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# APPRAISED MARKET VALUE OF TREES ON RESIDENTIAL PROPERTY WITH MOUNTAIN PINE BEETLE AND SPRUCE BUDWORM DAMAGE IN THE COLORADO FRONT RANGE

Richard G. Walsh, Ghebre Keleta, John P. Olienyk, and Eliot O. Waples

The work reported herein was funded, in part, by a U.S. Department of Agriculture, Forest Service project entitled: "Pilot Study to Develop Guidelines for Determining the Effect on Residential Property Values of Tree Mortality from Mountain Pine Beetle and Spruce Budworm," USDA Forest Service Cooperative Agreement No. 16-950-CA.

Department of Economics
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# ABSTRACT

The purpose of this study was to develop and apply a procedure for measuring the effect of mountain pine beetle and spruce budworm damage to trees on the market value of improved and unimproved mountain property in the Front Range of the Colorado Rocky Mountains. A representative sample of 21 real estate appraisers of Front Range mountain property were interviewed during the summer and fall of 1980. Appraisers gave their professional opinions concerning the contribution of trees to the market value of mountain property contingent on changes in several important forest quality variables including: number of trees six inches dbh or more on the property, on adjacent property in the near view, size of trees, expectation of insect damage, visible insect damage, distribution of trees, change in species, and presence of large specimen trees as illustrated by color photos. Market value of trees was estimated on the basis of the contingent value approach as recommended by the U.S. Water Resources Council guidelines for studies of the value of changes in environmental quality. Ordinary least squares regression techniques and tests of significance were applied in analysis of the data. The results of the study will contribute to an assessment of forest insect control programs, and to citizen participation in management decisions and cost sharing programs.

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## SUMMARY

The purpose of this study was to develop and apply a procedure for measuring the effect of forest quality on the market value of residential mountain property, in the opinion of real estate appraisers. In recent years, mountain pine beetle and spruce budworm infestations have affected forest quality on over 15 percent of the residential property in the Front Range of the Colorado Rocky Mountains, an area where private land has been increasingly converted from ranching to residential subdividions. By 1980, there were an estimated 62,000 mountain homes and 112,000 unimproved lots in mountain subdivisions in the Front Range. From 1970-1980, the number of unimproved lots increased at a compound rate of 6-7 percent annually, compared to 4.8 percent for mountain homes, 2.8 percent for residential housing in the state as a whole, and 1.1 percent for the United States.

A representative sample of 21 real estate appraisers of Front Range mountain property were interviewed during the summer and fall of 1980. Subdivisions in the vicinity of Estes Park were selected as representative of mountain subdivisions in the Front Range. It is a community of 3,000 people located 70 miled northwest of Denver at an elevation of 7,500 feet. The Roosevelt National Forest borders the area on the north, east, and south, with Rocky Mountain National Park on the west. The Continental Divide passes through the park with peaks over 14,000 feet in elevation. It represents the range of forest conditions in subdivisions in the Front Range, an area extending along the east side of the Rocky Mountains the length of Colorado from approximately 6,000 feet elevation to the Continental Divide with peaks over 14,000 feet. Ponderosa pine is common in stands averaging 160 trees six inches dbh or more per acre from 6,000 to 8,000 feet elevation with douglas fir occuring in moist north facing slopes at the higher end of the ponderosa pine range. Mountain pine beetle infestation turns ponderosa pine needles rust colored on dying trees. Spruce budworm infestation seldom kills douglas fir and white fir trees while discoloring of needles and defoliating stunts tree growth, causes top-kill, and die-back of branches.

Real estate appraisers gave their professional opinions concerning the contribution of trees to the market value of improved and unimproved mountain property contingent on several important changes in forest quality variables including: number of trees six inches dbh or more on the property, on adjacent property in the near view, size of trees, expectation of insect infestation, visible insect damage, change in species, distribution of trees, and presence of large specimen trees as illustrated by color photos.

The market value of trees was estimated on the basis of the contingent value approach, as recommended by an interagency committee of the U.S. government for studies of the value of changes in environmental quality. An iterative bidding technique recommended by the guidelines was adopted to assist appraisers in reporting their opinion as to the market value of trees, the point where offer and acceptance prices would be in equilibrium. Starting point was the specified value of improved and unimproved mountain property without trees. Respondents answered 'yes' or 'no' to random increases or decreases in value of a one acre tract until the best estimate of market value was identified. Appraisers were asked to assume that all other market conditions would remain unchanged except for attributes of forest quality. Ordinary least squares regression techniques and tests of significance were applied in analysis of the data.

In the opinion of real estate appraisers, forest quality was an important determinant of the value of residential mountain property which declined with distance. When preference for trees was rated on a five-point scale of importance, extremely important to not important, 71 percent reported that trees were very important on mountain property, compared to 48 percent on adjacent property in the near view, and 19 percent in the far view. There was considerable variation in the opinion of real estate appraisers as to the relative importance of trees compared to other attributes of the quality of mountain property. Overall, they rated trees as more important than rock outcroppings and topography, but less important than view of the mountains and nearness to streams and lakes.

Ordinary least square statistical methods were used to estimate the relationship of tree values to number of trees six inches dbh or more on improved and unimproved mountain property and other social economic variables. Number of observations of the relationship was 84 which proved sufficient for statistically significant analysis. The proportion of the variation in tree values explained by the independent variables in the equations was 0.31 and 0.34 as measured by $R^2$ adjusted for degrees of freedom. The overall equations were statistically significant at the 0.01 level as indicated by F values. All regression coefficients for the independent variables were significantly different from zero at the 0.01 to 0.12 levels. The usual tests of the assumption of the regression model including multicollinearity and heteroscedasticity revealed little or no significant effects on the study results. Alternative forms of the contingent value equations were tried including linear, semi-log and double-log forms. However, the quadratic form which includes a linear and a squared term for trees provided the best fit of the relationship.

The functions were condensed to show the relationship between the two variables of interest. All independent variables other than number of trees and number of trees squared were multiplied by their means and added to the constant. The following reduced functions were obtained for the relationship between the number of trees per acre and the market value (in $100s) of improved and unimproved mountain property:

$$\text{Market Value of Trees on Improved Property} = 50.6517 + 0.4107\text{TREES} - 0.0016\text{TREES}^2$$

$$\text{Market Value of Trees on Unimproved Property} = 44.4471 + 0.3091\text{TREES} - 0.0011\text{TREES}^2$$

The resulting functions provide a reasonable representation of the effect of trees on property values in the mid-range which is the relevant area of decision making. The functions should not be taken to the extreme of very low or very high number of trees. The total value functions were inverted U-shaped increasing at a decreasing rate to a maximum and then declining as the number of trees per acre increase. For example, the total value of trees on improved property increased from $5,460 per acre with 10 trees to $6,717 per acre with 50 trees, $7,569 per acre with 100 trees, to a maximum of $7,697 per acre with 128 trees. Thereafter, the contribution of trees to the market value of improved property fell with additional trees.

A similar relationship was obtained for the contribution of trees to the market value of unimproved property. However, trees contributed nearly $717 per acre more value to improved than to unimproved property with 10 trees per acre, $1,002 more value with 50 trees per acre, $1,133 more with 100 trees per acre, and $1,081 more at maximum value.

Younger appraisers who were trained and received certification in recent years were more sensitive to the value of trees on mountain property than their older peers. Tastes and preferences for trees were associated with the appraised market value of trees on Front Range mountain property. Other variables were controlled independent of the regression analysis. These included: location, lot size, topography, access, schools, utilities, land value at $20,000 per acre, and house value of $80,000, consistent with values reported in the study area.

The marginal value of trees on improved mountain property decreased from $38 per tree with 10 trees per acre to $25 with 50 trees, $9 with 100 trees, zero with 128 trees, and to -$7 with 150 trees. This indicates that with sustained insect infestation, the adverse effect on tree values would rise at an increasing rate. Also, forest management programs which thin over-stocked stands of ponderosa pine and doublas fir have a favorable effect on tree values in the long run as number of trees per acre are reduced to optimum levels.

Tree values would decrease by 0.14 percent with a one percent decrease in the number of trees six inches dbh or more on improved property, compared to 0.15 percent on unimproved property. The average elasticity of tree values with respect to number of trees was calculated in the range of 1-15 percent decreases from 106 trees per acre, all other variables unchanged. This would be the effect on tree values of a general outbreak of forest insects which killed 1-15 percent of the trees on mountain property. This compares to a study of tree values in the eastern United States in 1972 which reported that tree values would decrease by 0.13 percent with one percent decrease in number of trees 6 inches dbh or more on improved property in Amhurst, Mass. Apparently trees are somewhat more valuable in the arid western United States than in the east.

Tree values would decrease by .12 percent with each one percent decrease in the number of live trees six inches dbh or more on adjacent property in the near view. Average elasticity of tree values with respect to number of trees

in the near view was calculated in the range of 1-15 percent decrease from 106 trees per acre on adjacent property. This would be the external effect of insect damage to trees in a visual corridor which may extend several hundred yards from improved mountain property depending on topography.

Tree values would decrease by 0.94 percent with one percent increase in expectation of forest insect damage on improved property, compared to 0.92 percent on unimproved property. The average elasticity of tree values with respect to expectation of forest insect outbreak was calculated in the range of 1-50 percent of 106 trees per acre. This would be the effect on tree values of a general outbreak of forest insect infestation when forest entomologists predict that 50 percent of the trees on mountain property will be killed within five years.

Tree values would decrease by 2.48 percent with visible discoloration of needles from insect infestation of one percent of the trees on improved property, compared to 2.06 percent on unimproved property. The average elasticity of tree values with respect to visible insect damage was calculated in the range of 1-15 percent of 106 trees per acre. This would be the effect on tree values during the second year after a mountain pine beetle attack when needles appear rust color on dead trees; it would be the annual effect of spruce budworm infestation of douglas fir.

Tree values were also effect by visible insect damage on adjacent property in the near view as well as in the far view although the effect declines with distance. Trees values on improved property would decrease by 1.07 percent with visible discoloration of needles from insect infestation of one percent of the trees on adjoining property in the near view. Tree values on improved property would decrease by 0.16 percent with visible insect damage to trees in the far view. Thus, the total effect of visible insect damage was a decrease of 3.73 percent in tree value with one percent of the trees affected on the property, in the near view, and in the far view from improved property.

Tree values would decrease by 0.29 percent with one percent increase in non-forested clearing as a result of forest insect infestation of improved and unimproved property. The average elasticity of tree values with respect to distribution of trees was calculated in the range of 1-50 percent concentration of trees on one-half of a one-acre tract. This would be the effect on tree values of insect infestation killing all of the trees on part of the property.

Tree values would increase by 0.05 percent with each one percent increase in the proportion of douglas fir to ponderosa pine on improved property, compared to 0.06 percent on unimproved property. The average elasticity of tree values with respect to species of trees was calculated in the range of 1-100 percent of 106 trees per acre. Appraisers considered douglas fir slightly superior to ponderosa pine on the basis of forest insect infestation resistance.

Tree values would decrease by 1.8 percent with the loss of one percent specimen trees (one specimen tree per acre) from forest insect infestation on improved property, compared to 2.4 percent on unimproved property. Average elasticity of tree values with respect to specimen trees 24 inches dbh or more

was calculated in the range of 1-5 percent of 106 trees of mixed age per acre, with all other variables unchanged. When a few large specimen are the only trees present in isolated stands, loss of one large tree reduces the value of mountain property more than the loss of five specimen trees interspersed in mixed stands of 106 trees per acre six inches dbh or more.

Tree values would decrease by 0.53 percent with each one percent decrease in the average size of live trees surviving forest insect infestation on improved property, compared to 0.54 percent on unimproved property. Statistical analysis of the effect of tree size on value showed that with reforestation after insect infestation, value would rise over the growth cycle of trees.

Full recovery of damages to Front Range forest would occur approximately 50 years after initial forest insect attack when it is estimated that regrowth of an insect damaged ponderosa pine forest would reach 7 inches dbh. Including the effect of regrowth of an insect damaged forest has a substantial effect on the calculation of annual value from the reported present values. It reduces the present value per dollar of annual value by 31-37 percent.

The results were applied to the problem of efficient insect control decisions by owners of mountain property, based on the market value of trees in the opinion of real estate appraisers. The optimum number of trees to protect per acre, on grounds of economic efficiency, would occur where marginal value per tree equals marginal cost of control. With marginal costs of forest management including insect control equaling about $0.90 per tree annually, the optimum number of trees to protect on improved mountain property would be 100 trees per acre. This would be equivalent to an insect control program which sprayed every three years at marginal cost of $2.70 per tree or a thinning program to encourage vigorous growth every ten years at a marginal cost of approximately $9 per tree. With the protection of 100 trees per acre, average annual market value to owners would equal $7.57 per tree. Thus, the annual benefit cost ratio of an owner's insect control program would equal 8.4.

The economic efficient level of expenditure on forest insect control by an association of homeowners and/or a public agency would be more than an individual owner. The average market values reported by the sample of real estate appraisers were expanded to the population of 62,000 improved properties and 112,000 unimproved properties in the Front Range in 1980. For example, with 15 percent fewer trees on adjacent property in the near view, the present value of trees accruing to improved property would decrease by $11.1 million. This represents an external effect of insect infestation over which property owners have no control.

The results of this study will contribute to a Region II, U.S.D.A. Forest Service, Forest Insect and Disease Management Program. The information is an essential part of an assessment system designed to investigate the impacts of mountain pine beetle and spruce budworm infestation on forest resources in the Front Range of Colorado and in similar areas in the western United States. The assessment will include biological and psychological components as well as mountain property values.

In addition to the mountain property values reported here, the general public may value the preservation of forest quality on private land and be willing to pay for the option to view outstanding forest resources in the future, the knowledge that forest quality exists and is protected, and the satisfaction from bequest of forest quality to future generations. Moreover, the market value of mountain property is constrained by limited household income of buyers, availability of leisure time, and other variables. There may be psychological values associated with forest quality which exceed the economic measure of values reported here.

Also, there may be long-run ecological values of forest quality which are not included here. It is difficult for biologists to predict what these might be let alone measure and incorporate them into a mountain property value estimate. For this reason it seems that the present estimate of the effect of forest quality on mountain property value represents a conservative estimate of the total value to society of protecting forest quality. The inability of economic analysis to place a dollar value on unknown ecological effects should be recognized in making decisions about forest insect control programs.

# APPRAISED MARKET VALUE OF TREES ON RESIDENTIAL PROPERTY WITH MOUNTAIN PINE BEETLE AND SPRUCE BUDWORM DAMAGE IN THE COLORADO FRONT RANGE

Richard G. Walsh, Ghebre Kelta, John P. Olienyk, and Elliot O. Waples*

A major outbreak of mountain pine beetles, Dendroctonus ponderosae occurred in 1965 and continues to the present on two million acres of mixed age ponderosa pine, Pinus ponderosa var. scopulorum Engelm., in the Front Range of the Rocky Mountains, Colorado. Overall loss of trees in the area extending 180 miles from the Wyoming border south to Canon City, Colorado, has been estimated as 15 percent of ponderosa pine trees six inches dbh or more. Loss of trees in the Roosevelt National Forest located in the northern Front Range was reported as 25 percent with less damage in the Arapahoe, Pike, and Isabel National Forests in the southern Front Range [McCambridge, Hawksworth, Edminster, and Laut, 1981]. The insects attack and kill progressively larger trees with the rate of kill function rising from 1-9 inches dbh and constant from 10-14 inches dbh or more, although some large trees survive. A study of Lory State Park located in the northern Front Range reported 25 percent of the trees were lost and 44 percent of the merchantable board feet value equal to 984 board feet per acre valued at $14. Thus, with an average 15 percent loss of trees on two million acres of ponderosa pine in the Front Range, the merchantable timber loss would equal approximately 1,180 million board feet valued at $16.8 million.

A major outbreak of western spruce budworm, Choristoneura occidentalis, Freeman, occurred in 1974 and continues to the present time on 1.52 million

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acres of mixed age douglas fir, Pseudomtsuga menziesii, var glauca (Beissn.) Franco, on moist north facing slopes of the Front Range in Colorado. Spruce budworm also have attacked white fir in the southern Front Range. Few trees have been killed by spruce budworm thus far, however, discoloration and defoliation of newly grown needles is highly visible. Several consecutive years of defoliation stunts tree growth, causes top-kill, and die-back of branches. If the infestation continues for approximately ten years, it will eventually kill host trees.

In addition to the loss of merchantable timber, forest insect management decisions require knowledge of the economic value of trees in the residential areas of the forest where the value of trees for shade and aesthetic quality exceeds their value for conversion into wood products [Averill, Gunter, Lister, and Sonnen, 1977]. The discoloration of needles caused by insect infestation detracts from the aesthetic beauty of the forest in the short run. As dead trees are removed or decay, the long run effect is to reduce the density of the stand of live trees and thus change the quality of the forest. While the unsightliness resulting from pine beetle and spruce budworm infestation is very obvious, even to the most casual observer, the long run effect is more subtle. Once the dead trees decay or are removed, it is likely that most purchasers of land in mountain subdivisions will be unaware that an insect attack ever occurred in the area. The fact remains, however, that the value of the forest on property where insect damage has occurred may be significantly different from what it would have been in the absence of the insect damage. Thus, the demand for property in mountain subdivisions without the damage may be higher than after the insect attack. The demand for mountain property as residential homesites and thus its market value may decrease.

The purpose of this study was to develop and apply a procedure for measuring the effect of mountain pine beetle and spruce budworm damage on the market value of trees on improved and unimproved mountain property in the Front Range of Colorado. Specific objectives were:

(1) determine the loss in market value of residential property from mountain pine beetle and spruce budworm infestation both on-site and on adjoining property in the near view;

(2) contribute to control decisions by providing information on the cost-effectiveness of insect control programs;

(3) suggestion application of the research results to improve citizen participation in management decisions and cost sharing programs.

The procedure adopted was to interview a representative sample of 21 appraisers of Front Range mountain property during the summer and fall of 1980. Appraisers reported their professional opinion concerning the contribution of trees to the market value of improved and unimproved mountain property contingent on changes in forest quality variables including: number of trees six inches dbh or more on the property and on adjacent land in the near view; size of trees, expection of insect damage, visible insect damage, change in species, presence of large specimen trees, and distribution of trees. Market value of trees was estimated on the basis of the contingent value approach, as recommended by the U.S. Water Resources Council [1979] for studies of the economic value of changes in environmental quality. Ordinary least squares regression techniques and tests of significance were applied in analysis of the data.

The results of this study will contribute to a Region II, USDA Forest Service, Forest Insect and Disease Management program. This information is an essential part of an assessment system designed to investigate the impacts of mountain

pine beetle and spruce budworm infestation on forest resources in the Front Range of Colorado and in similar areas in the western United States. This assessment will include biological, recreational, economic, and psychological components. The overall assessment system will be used to measure: (1) the benefits of alternative infestation control programs, (2) the costs of alternative programs to reduce or remove infestation, (3) the costs of monitoring and enforcement of alternative regulations, and (4) where chronic unemployment exists, the indirect or secondary benefits and costs of alternative programs. The information will be used to help formulate and evaluate alternative actions by public and private land managers to lessen the impact of insect damage to forest resources.

A review of previous research revealed several related studies. One study produced acceptable results for the eastern U.S. of dollar loss in residential property value from tree mortality caused by the gypsy moth [Payne, White, McCay and McNichols, 1973]. Trees contributed an average of 7 percent to the value of $25,000 to $50,000 homes on lots averaging 20,000 square feet (about one-half acre) in Amherst, Massachusetts. The statistical relationship of property value contributed by trees (V) to number of trees 6 inches dbh and larger (t) had the following form:

$$V = \$300\ t - \$5.22\ t^2$$

$$N = 212 \qquad R^2 = .78$$

The value added by trees increased at a decreasing rate to a maximum value of $4,310 with 29 trees and then declined. The study included no properties with more than 50 six-inch dbh and larger trees on lots of 20,000 square feet. A tree value of $1,950 was assigned to lots with 50 or more trees.

The 1972 study found that color photos in sets of 3-5 provided a meaningful way to study tree values. The market value of 212 residential properties was estimated by a panel of nine real estate appraisers. The appraiser values were within one percent of the values assigned by a sample of 200 homeowners, each evaluating 10-15 photos. Values from tax assessor records were not reliable measures of market value. The appraiser survey showed that tree values were significantly related to the value of the house, size of house, size of lot, and neighborhood. Thus, these factors should be controlled in future studies. Number of trees below 6 inches dbh was not an important determinant of value, nor was the percent of land covered by tree crowns.

In a subsequent study, Payne and Strom [1975] asked a panel of real estate appraisers to value unimproved land based on black and white photos of seven architectural model sites in which all variables were held constant except number of trees and tree configuration. They found that a model of a 12-acre tract of open land zoned for development in Amherst, Massachusetts, was valued at an average of $1,490 per acre when no trees were present, $1,860 when 33 percent forested, $2,050 when 66 percent forested, and $1,830 when 100 percent forested. The 12-acre tract included 14 housing lots, 840 linear feet of road and two areas of common land, each occupying two-thirds of an acre. Size of trees, number of trees, and size of lot were not reported. Model trees represented mixed northern hardwoods. The only land value determinants allowed to vary were the amount and distribution of tree cover. Scattered arrangements of trees were valued more highly than concentrated arrangements. Topography of the site was nearly flat. They concluded that there may be significant interaction of tree values with topography, size of tract, and other variables.

Morales, Boyce and Favaretti [1975] analyzed 14 variables which explained the sales price of 60 residential properties in Manchester, Connecticut, with and without mature trees. They concluded that mature trees added 6-9 percent to the sales price of residential properties, with other variables constant. Purcell [1956] compared the sales price of residential property zones in Toronto, Canada, with and without trees, and concluded that trees contributed an average of $300 per tree. Paige [1964] estimated that 20,000 street trees in Beverly Hills, California, contributed an average of $900 per tree to property values. Love [1977] interviewed 22 property owners in the Front Range of Colorado to compare the value of tracts with and without trees in the same mountain subdivision. He concluded that ponderosa pine trees added 10-60 percent to the value of unimproved mountain lots.

The remainder of this report is organized into 13 sections. We outline the concept of the contribution of trees to the appraised market value of mountain property in Section 2. The following two sections describe the study area, subdivision development trends, and the method of research. Section 5 reports the psychological importance of trees to appraisers, and the relative importance of trees compared to other attributions of environmental quality. Sections 6 and 7 present the empirical findings of this study with respect to the market value of trees on the property and on adjacent land in the near view. Section 8 presents the effect of tree size on the market value of trees. This is followed by a section on the effects of other aspects of forest quality including expectation of insect damage, visible insect damage, large specimen trees, change in species, and distribution of trees on mountain property. Section 10 contains a projection

of the recovery of damages as future regrowth occurs in an insect damaged forest. This is followed by a section which brings the study results together with applications to insect control decisions. Section 12 contains the main conclusions of this report and a discussion of the limitations of economic analysis when applied to problems of forest quality. The appendix contains the sources of literature and a copy of the questionnaire.

## CONTINGENT VALUE APPROACH

The direct interview method used in this study was recently recommended by the U.S. Water Resources Council [1979] as providing acceptable measures of the economic value of changes in environmental quality. The inter-agency committee established procedures for application of a contingent value approach based on the informed opinion respondents. In this study, appraisers were asked to report the market value of improved and unimproved mountain property contingent on hypothetical changes in forest quality.

An iterative bidding technique recommended by the Council was adopted to assist appraisers in reporting their opinion as to the market value of trees, the point where offer and acceptance prices would be in equilibrium. Starting point was the specified value of improved and unimproved mountain property without trees. Respondents answered 'yes' or 'no' to random increases or decreases in value of a one acre tract until the best estimate of market value was identified. Appraisers were asked to assume that all other market conditions would remain unchanged except for attributes of forest quality.

The procedure was repeated for each of three levels of: forest density on the property, on adjacent land in the near view, and tree size. Respondents were shown color photos depicting four levels of forest density. These included: a low number of trees, medium, medium-high, and high. The three levels of tree size were 3 inches, 6 inches, and 12 inches dbh. Then appraisers were asked to report how their high value of trees would change if conditions changed in the following ways: (1) forest entomologists report that one-half of the trees on the lot would be killed by insect infestation within five years; (2) fifteen percent of the trees on the lot would have reddish needles because of insect

damage; (3) predominant species of trees on the property would change from ponderosa pine to douglas fir; (4) arrangement of trees would change from a scattered pattern to a concentrated grouping on one half of the lot.

Appraisers were asked to assume that all other conditions would remain unchanged except for the attributes of forest quality. It was assumed that the improved and unimproved property valued was located in the same subdivision in the vicinity of Estes Park, Colorado. The size of lot was held constant at one acre, roughly 200 x 200 feet. Ponderosa pine trees were in a scattered arrangement. Topography was specified as gently sloping land with little or no rolls. Access was by public road in front of the property. All schools were equally close. The house was valued at $80,000 and included 1,500 to 2,000 feet of living space, two baths, two-car garage, fireplace, three bedrooms, and a family room. Land value was $20,000 consistent with values in the study area.

A combination of factors contributed to the realism of the simulated market situation. There is an active market for improved and unimproved mountain property in the Front Range of Colorado. The market provides an established routine method of buying and selling mountain property on which forest quality is one important attribute of value. It was logical to expect that changes in forest quality would affect the market value of mountain property. Changes in the quality of forest resources have affected the value of mountain property in the past. The method of payment introduces the exclusion principle in that forest quality can be appropriated by owners in the value of mountain property. Individuals can purchase a desired level of forest quality in the market for mountain property and exclude other individuals from trespassing on their property. However, the scenic quality of trees on private land also has public good aspects; if it is protected by individual homeowners, it is equally available

to others to view from the distance of a nearby road or adjacent property.

No appraisers in the sample rejected property values as an appropriate method of payment for trees. It was clearly the best available common denominator to compare the relative values assigned by the sample of real estate appraisers. This relatively neutral measure of value was selected over alternatives such as annual tax, insect control association dues, or commercial insect control and management fees. Real estate appraisers are experts at assigning value to the attributes of residential property, including forest quality. Question 7 was prepared to ask respondents who reported no market value of trees. Is it because owners are believed to receive no benefits from trees, income constrains owner's ability to pay, or they believe it is unfair to expect property owners to pay for forest quality which should be provided by public agencies? No appraisers in the sample assigned a zero value to forest quality, so this question was not used.

Tests of the possibility of strategic bias were performed as suggested in the case of contingent valuation studies [U.S. Water Resources Council, 1979]. Respondents who engage in strategic behavior may overstate the market value of trees in order to gain government subsidized insect control programs, or understate market values in order to avoid higher assessments by insect control districts. If respondents as a group biased their responses, a frequency distribution would show clustering of values at abnormally high or low levels. The distributions of tree values reported did not indicate abnormal behavior, which suggests that there was no strategic bias of the study results. Moreover, strategic bias would violate the appraiser code of ethics and could lead to loss of certification.

Clawson and Knetsch [1966] have proposed enhanced private land values as one measure of the benefit of public resource management. The contingent value approach was first applied by Davis in a 1963 study of the consumer surplus benefit of recreation activities in the Maine woods. He asked recreationists to report the maximum additional cost they would pay before deciding to discontinue the activities at the study site. The procedure has been successfully applied to value recreation resources in the Main woods [Knetsch and Davis, 1966], a water basin in British Columbia [Meyer, 1974], water quality in Colorado [Walsh, Greenley, Young, McKean, and Prato, 1978], fishing in Washington State [Mathews and Brown, 1970], the Western Flyway [Hammack and Brown, 1974], wildlife in the Southeastern region [Horvath, 1974], and air quality in New Mexico [Randall, Ives, and Eastman, 1974] and at the Glen Canyon National Recreation Area [Brookshire, Ives, Schultze, 1976].

Many economists have reservations about the accuracy of values obtained from contingent value questions [Freeman, 1979]. For example, Samuelson [1954] warned that ". . . it is in the selfish interest of each person to give false signals, to pretend to have less interest . . ." in forest quality when he suspects that he may actually have to pay the amount he reveals as his willingness to pay. In this case, respondents were asked to estimate market values in what is clearly a hypothetical situation. Respondents knew that the study was sponsored by the University for scientific purposes, thus, they could infer that responses would have no direct effect on market prices actually paid.

It is notable that objections to the contingent value approach have been primarily theoretical, as empirical evidence of systematic bias is at best inconclusive. Davis, who pioneered the method in a study of the recreation

benefits of the Maine woods, concluded that the reported values were not significantly different from those obtained by the market-related travel cost approach [Davis, 1963; Knetsch and Davis, 1966]. Randall and associates developed refinements in the contingent valuation technique and presented a persuasive case for its effectiveness in the valuation of environmental quality. They studied the benefits from improved air quality and other environmental amenities in the Four Corners area of New Mexico [Randall, Ives and Eastman, 1974] and the Glen Canyon National Recreation Area [Brookshire, Ives and Schultze, 1976]. They found no measurable strategic behavior by environmentalists compared to other respondents. Replication of the studies resulted in similar values. Bohm [1972] conducted a controlled experiment comparing five alternative measures of willingness to pay for a public good, including actual payment in cash of the stated willingness to pay. He found no significant difference in values reported by five groups, each presented with an alternative willingness to pay format. Bohm [1979] concluded that the theoretical objections to the contingent valuation approach could be resolved by application of an interval method. Two benefit functions would be derived, based on minimum and maximum incentives to misrepresent willingness to pay. The midpoint of the interval would represent the most acceptable value.

The willingness to pay measure of the value of forest quality was selected over the alternative, willingness to sell or accept compensation for reduced forest quality. A number of studied including Bishop and Heberlein [1979] have found that willingness to sell values including actual cash sales are considerably higher than willingness to pay, whether the latter is measured by the contingent value or the travel cost approach. This is the expected result, as willingness

to pay would be constrained by limited household income and time budgets as well as other variables [Gordon and Knetsch, 1979]. More realistic estimates of tree values are expected under these constraints. The acceptance of compensation would increase the respondent's level of income and result in value estimates which are unrestrained by the utility of dollars normally earned as income.

The contingent value approach is gaining broad acceptance. It is generally recognized that the method requires careful wording of questions and well-defined market situations with which the respondent is familiar. In several of the studies cited above more than one approach was used. No one method has emerged superior in all cases, and there is need for further research to tests the effectiveness of alternative willingness to pay formats.

## STUDY AREA

The study area was the Front Range of the Rocky Mountains of Colorado shown as the shaded area on the map of the state presented as Figure 1. Appraisers were asked to assume that the improved and unimproved property was located in the same subdivision in the vicinity of Estes Park, Colorado, identified as area "C" on the map. Estes Park is a community of 3,000 people located 70 miles northwest of Denver at an elevation of 7,500 feet. The Roosevelt National Forest borders the Estes Park area on the north, east, and south, with Rocky Mountain National Park on the west. The Continental Divide passes through the park with peaks over 14,000 feet in elevation.

Selection of the Estes Park area to represent subdivisions in the Front Range allowed other important variables to be controlled by assumption. Appraisers were asked to assume that access to improved and unimproved property was by public road in front of the property. All schools were equally close. Available utilities included electricity, sewer and water in front of the lot. Size of lot was held constant at one acre, roughly 200 by 200 feet. Topography was specified as gently sloping land with little or no rolls. Ponderosa pine trees were in a scattered arrangement. The house was valued at $80,000 and included 1,500 to 2,000 square feet of living space, two baths, two-car garage, fireplace, three bedrooms, and a family room. Land value was $20,000 for a one-acre tract with no trees. Both house and lot values were consistent with values reported in the study area.

The Front Range extends along the east side of the Rocky Mountains the length of Colorado and is bordered on the north by Wyoming and on the south by New Mexico. The eastern boundary of the Front Range is approximately the 6,000 foot elevation contour. The western boundary is the western Larimer county line,

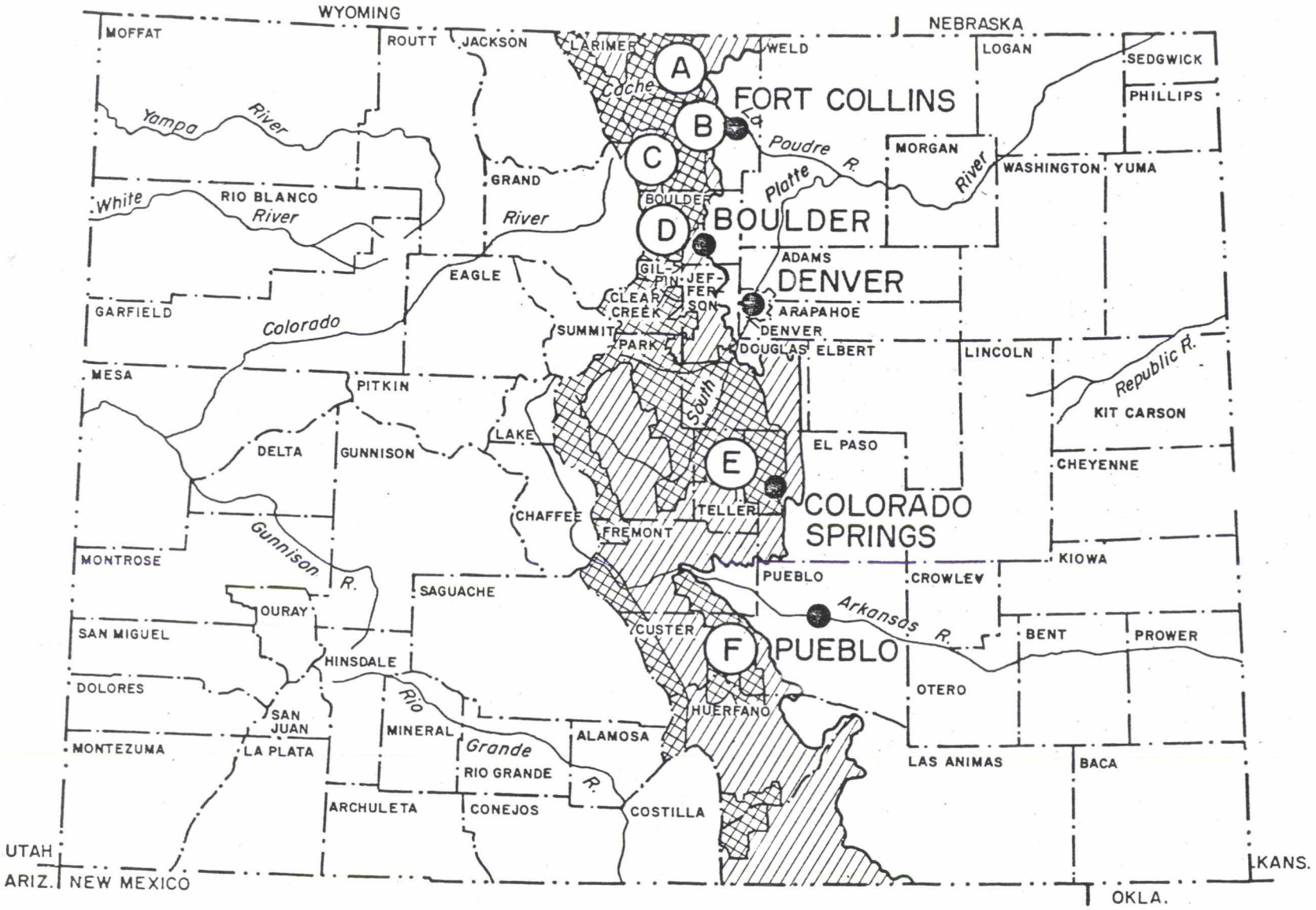



Figure 1. The Front Range Study Areas, Rocky Mountains, Colorado, 1980.

which divides the North and South Platte River Basins, from the Wyoming border to the Continental Divide which extends through Rocky Mountain National Park to approximately the center of the state where the boundary becomes the western Park and Fremont county lines. To the south, the western boundary is the crest-line of the Sangre de Cristo mountain range.

The Front Range constitutes an area of approximately 8.5 million acres equal to 12.8 percent of the 66 million acres in the state. Public land in National Forests total 3.2 million acres, equal to 37.6 percent of the total Front Range. Included are the 2.2 million acres contained in the Pike and San Isabel National Forests in southcentral Colorado, part of the Arapahoe National Forest located on the Front Range, and Roosevelt National Forest in northcentral Colorado with nearly 1 million acres. National Forests on the Front Range equal 23.7 percent of the 13.5 million acres of National Forests in the state.

Second growth forest interspersed with meadows of shrubs, grasses, and wildflowers occurs throughout the Front Range from the Wyoming border south to New Mexico. Ponderosa pine is common in stands averaging 160 trees per acre from 6,000 to 8,000 feet elevation in a semi-circle down the Front Range of the Rocky Mountains, across the southern end of the state, and a third of the way up the west side. Douglas fir occurs on moist north-facing slopes at the higher end of the ponderosa pine range. Lodgepole pine occurs from 8,000 to 10,500 feet in central and northern Colorado. Englemann spruce and subalpine fir forests are located at 9,000 to 11,500 feet in scattered stands. Aspen occur anywhere from 8,000 to 10,000 feet. Bristlecone and limber pine are found near timberline at 11,500 feet. Above timberline, the growing season is short and forests disappear. Small grasses, shrubs,

and broad-leaved plants are characteristic of the arctic tundra. Much of the area consists of bare rock and the open lackscape provides vistas of many miles.

Colorado has more mountains than any other state in the Continental U.S., a substantial proportion on the Front Range. The state is dominated by the high peaks of the southern Rocky Mountains. There are 831 peaks between 11,000 and 14,000 feet elevation and 53 peaks over 14,000 feet. The Continental Divide passes through the midsection of the state with massive peaks, long ridges, and deep valleys carved by vast sheets of moving ice some 10,000 years ago. The mountains are criss-crossed by deep canyons carrying streams both east and west. The headwaters of the Arkansas and South Platte Rivers originate at the higher elevations of the Front Range. Many lakes occupy depressions left by receding glaciers. Streams originate from alpine lakes with pristine water quality and gradually yield to degradation as elevation diminishes and human encroachment increases. Most of the existing and potential wilderness areas in the state occur at elevations of 9,000 feet to over 14,000 feet and consist principally of ice and rock, with thin soil supporting forest below timberline of 11,500 feet.

The Front Range is cool and dry with summer temperatures seldom rising above 90 degrees Fahrenheit which is comfortable when accompanied by low humidity. Snow and rainfall yield 15 to 30 inches of water annually. Many wildlife species are present including bald and golden eagles, bighorn sheep, black bear, mule deer, elk, moose, beaver, marten, and other small mammals, birds and fish (brook, brown, cutthroat, and rainbow trout).

The Front Range of the Rocky Mountains in Colorado has been subject to increasing subdivision into residential tracts. Table 1 shows that the number of mountain homes on the Front Range increased from less than 40,000

Table 1. Estimated Number of Mountain Homes, Front Range of Colorado, 1970 and 1980.

| County | Front Range Area | | Number of Mountain Homes[a] | | Homes Per Square Mile | | Proportion of Seasonal Recreation Homes, 1980 | |
|---|---|---|---|---|---|---|---|---|
| | Proportion of County | Square Miles | 1970 | 1980 | 1970 | 1980 | Number | Percent |
| Larimer[b] | 80% | 2,091 | 3,800 | 5,000 | 1.8 | 2.4 | 1,200 | 24.0 |
| Boulder | 65% | 488 | 3,527 | 4,973 | 7.2 | 10.2 | 1,213 | 24.4 |
| Gilpin | 100% | 149 | 1,164 | 2,060 | 7.8 | 13.8 | 94 | 4.6 |
| Clear Creek | 100% | 394 | 2,505 | 2,756 | 6.4 | 7.0 | 301 | 10.9 |
| Park | 100% | 2,166 | 2,217 | 6,230 | 1.0 | 2.9 | 348 | 5.6 |
| Jefferson | 85% | 667 | 8,403 | 13,613 | 12.6 | 20.4 | 1,628 | 11.9 |
| Douglas | 85% | 717 | 3,585 | 7,170 | 5.0 | 10.0 | 860 | 12.0 |
| Teller | 100% | 554 | 2,190 | 5,782 | 4.0 | 10.4 | 1,006 | 17.4 |
| El Paso | 25% | 540 | 4,551 | 5,780 | 8.4 | 10.7 | 786 | 13.6 |
| Fremont | 85% | 1,328 | 1,594 | 1,992 | 1.2 | 1.5 | 235 | 18.0 |
| Custer | 100% | 737 | 891 | 1,096 | 1.2 | 1.5 | 199 | 18.2 |
| Pueblo | 10% | 240 | 1,361 | 1,402 | 5.7 | 5.8 | 206 | 14.7 |
| Huerfano | 85% | 1,341 | 1,609 | 2,012 | 1.2 | 1.5 | 301 | 15.0 |
| Las Animas | 40% | 1,918 | 2,141 | 2,398 | 1.1 | 1.3 | 10 | 0.4 |
| TOTAL | | 13,334 | 39,538 | 62,264 | 3.0 | 4.7 | 8,387 | 13.5 |

a. These estimates are based on number of residential units reported by the 1970 U.S. Census [U.S. Department of Commerce, 1973] updated to 1980 on the basis of change in population from 1970 to 1980. Number of residential units in the Front Range for Larimer, Douglas, Fremont, and Huerfano Counties were estimated on the basis of residential units per square mile in neighboring mountain counties. Number of seasonal recreation homes in these counties was estimated on the same basis. Seasonally vacant housing units were reported by the U.S. Census for other counties.

b. Includes the Estes Park incorporated area with an estimated 746 housing units in 1970 and 1,254 in 1980; the Front Range excluding the eastern two and one-half ranges with 3,000 housing units in 1970 and 3,450 in 1980; and the eastern two and one-half ranges with an estimated 54 housing units in 1970 and 296 in 1980.

in 1970 to over 62,000 in 1980 or by 60 percent. By 1980, the number of mountain homes in Park County was nearly three times 1970 levels, two and one-half times in Teller County, and nearly doubled in Gilpin, Jefferson, and Douglas Counties. With 2.6 persons per household, the population of the Front Range was estimated as 100,000 in 1970 and 162,000 in 1980. To put this in perspective, it was equivalent to 7.5 persons per square mile in 1970 and 12.2 persons in 1980.

The increase in population living on the Front Range during the past decade has been nearly twice the 30 percent increase in Colorado's population, and nearly 5.3 times the 11.4 percent increase in population of the United States. Population growth on the Front Range was equivalent to a compound rate of 4.8 percent per year compared to 2.8 percent for the state as a whole, and 1.1 percent for the United States.

Seasonal recreation home population on the Front Range in 1980 was estimated as nearly 22,000 persons and permanent residents 140,000 persons. There were an estimated 8,400 seasonal recreation homes on the Front Range in 1980, equal to 13.5 percent of total mountain homes. The proportion of seasonal recreation homes to total homes ranged from less than one percent in Las Animas County in southern Colorado to more than 24 percent in Boulder County near Denver.

Table 2 shows that the total number of lots, both improved and unimproved, in mountain subdivisions on the Front Range increased from 97,000 in 1970 to 174,000 in 1980 or about 80 percent. Unimproved means that the lots have been plotted and a subdivision has been filed but mountain homes have not been constructed. In 1970, the total number of subdivided lots was nearly 2.5 times the number of improved lots on which a mountain home had been constructed. By

Table 2. Estimated Number of Subdivided Lots in Mountain Subdivisions on the Front Range of Colorado, 1970 and 1980.

| County | Lots in Mountain Subdivisions | | | |
|---|---|---|---|---|
| | Number of Lots[a/] | | Total Acres[b/] | |
| | 1970 | 1980 | 1970 | 1980 |
| Larimer | 9,350 | 14,000 | 20,159 | 30,184 |
| Boulder | 8,676 | 13,924 | 18,705 | 30,020 |
| Gilpin | 2,863 | 5,768 | 6,173 | 12,436 |
| Clear Creek | 6,162 | 7,177 | 13,285 | 15,474 |
| Park | 5,454 | 17,444 | 11,759 | 37,609 |
| Jefferson | 20,671 | 38,116 | 44,567 | 82,178 |
| Douglas | 8,819 | 20,076 | 19,014 | 43,284 |
| Teller | 5,387 | 16,190 | 11,614 | 34,906 |
| El Paso | 11,195 | 16,184 | 2,576 | 34,893 |
| Fremont | 3,921 | 5,578 | 8,454 | 12,026 |
| Custer | 2,192 | 3,069 | 4,726 | 6,617 |
| Pueblo | 3,348 | 3,926 | 7,218 | 8,464 |
| Huerfano | 3,958 | 5,634 | 8,533 | 12,147 |
| Las Animas | 5,267 | 6,714 | 11,356 | 14,475 |
| TOTAL | 97,263 | 174,339 | 209,699 | 375,875 |

a. The Census of Housing does not include subdivided lots and their number has not been tabulated for all counties on the Front Range. The number of lots in mountain subdivisions were estimated on the basis of a study underway of rural subdivisions in Larimer County [Waples, 1981]. The number of lots in mountain subdivisions on the Front Range of Larimer County was reported as 8,850 in 1970 and approximately 13,000 in 1980, excluding the eastern two and one-half ranges and the Estes Park incorporated area. It was assumed that Estes Park and the eastern two and one-half ranges contained 500 lots in 1970 and 1,000 in 1980. The ratio of subdivided to improved lots was estimated as 2.46 in 1970 and 2.80 in 1980. It was assumed that there are at least as many subdivided lots relative to improved lots in other Front Range counties as in Larimer County.

b. With 2.156 acres per lot as reported for a sample of 64 improved mountain homesites on the Front Range in 1980.

1980, the number of subdivided lots was 2.8 times the number of improved lots on the Front Range of Colorado. To put this in perspective, at the built-out rate of 2,272 mountain homes per year from 1970 to 1980, the available supply of subdivided lots constituted a 50 year supply.

The 80 percent increase in supply of building sites on the Front Range during the past decade was nearly one-third greater than the 60 percent increase in demand for mountain homes. It was 2.7 times the 30 percent increase in demand for residential units in the state of Colorado, and nearly seven times the 11.4 percent increase in demand for housing units in the United States. Growth in subdivided lots in mountain subdivisions on the Front Range was equivalent to a compound rate of approximately 6-7 percent per year.

Total land use by mountain subdivision in 1980 was 378,000 acres equal to 590 square miles. This was equivalent to 4.4 percent of the 12,334 square miles on the Front Range of Colorado. In 1980, the 62,000 mountain homes occupied an estimated 134,000 acres or 1.6 percent of the land on the Front Range. In the same year the 112,000 unimproved lots in mountain subdivisions contained a total of nearly 242,000 acres or 2.8 percent of the land area on the Front Range. These estimates are based on an average of 2.156 acres of land per lot in mountain subdivisions as reported for a sample of 64 improved mountain homesites on the Front Range in 1980.

## SURVEY DESIGN

The basic economic data for this study were obtained from interviews with a representative sample of 21 real estate appraisers during July, August, and September, 1980. This stratified sample was selected to represent the geographic distribution of mountain real estate appraisers active in the Front Range. Appraisers were interviewed by appointment at their places of business in Denver, Colorado Springs, Fort Collins, Boulder, Greeley and Loveland, Colorado. All interviews were taken by Dr. Eliot O. Waples, professor and past chairman of the Department of Finance and Real Estate, College of Business, Colorado State University, Fort Collins.

Table 3 shows that the appraisers interviewed were an impressive group of experts in the field of estimating the market value of real estate. Overall, their appraisal experience averaged 16 years with an average of 12 years appraising mountain real estate. Their appraisal experience ranged from 5-45 years, and years experience appraising mountain real estate 4-31 years. Fifteen were certified real estate appraisers, with one or more professional designations by the Appraisal Institute and the Society of Real Estate Appraisers. Six were working toward professional designation when interviewed, three of which have since received a certificate of designation. These six junior appraisers had an average of eight years of appraisal experience, and seven years experience appraising mountain real estate. Their appraisal experience ranged from 5-10 years, and years experience appraising mountain real estate 4-10 years.

Certification as a professional real estate appraiser requires many years of field experience, course work, examinations, and adherence to a strict code of ethics. Once certified, an appraiser is required to maintain his qualification

Table 3. Years of Experience and Types of Certification, 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Appraisers Interviewed | Years of Experience | | Types of Certification | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Real Estate, Total | Mountain Real Estate | Member, Appraisal Institute (MAI) | Counselor, Real Estate (CRE) | Senior Residential Appraiser (SRA) | Residential Member Appraisal Ins. (RM) | Senior Real Property Appraiser (SRPA) | Professional Engineer | None |
| 1 | 7 | 7 | | | | X | | | |
| 2 | 8 | 4 | a/ | | | | | | |
| 3 | 17 | 15 | X | X | | | | | |
| 4 | 15 | 15 | | | X | X | | | |
| 5 | 22 | 22 | X | | | | | | |
| 6 | 15 | 15 | X | X | | | | | |
| 7 | 5 | 5 | a/ | | | | | | |
| 8 | 45 | 4 | X | | | | X | | |
| 9 | 22 | 8 | X | | | | | | |
| 10 | 16 | 16 | X | X | | | X | X | |
| 11 | 28 | 15 | X | X | | | X | | |
| 12 | 19 | 19 | X | | | | X | | |
| 13 | 10 | 10 | | | | | | | X |
| 14 | 8 | 8 | | | a/ | | | | |
| 15 | 10 | 7 | | | X | | | | |
| 16 | 31 | 31 | X | | | | | | |
| 17 | 5 | 5 | X | | | | X | | |
| 18 | 9 | 6 | | | a/ | | | | |
| 19 | 8 | 8 | | | | a/ | | | |
| 20 | 25 | 25 | | | | X | | | |
| 21 | 8 | 5 | | | | X | | | |
| Total | 16 | 12 | 10 | 4 | 2 | 4 | 5 | 1 | 1 |

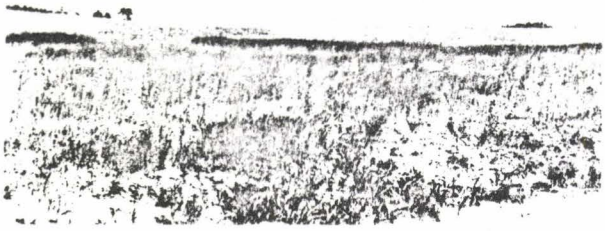
a. Candidate for designation

through continuing education. For example, to become a Member of the Appraisal Institute (MAI) requires 5-10 years of course work, numerous examinations, and many examples of appraisal work on all types of property. Market value estimates by appraisers with the MAI designation are widely accepted by the courts, lenders, investors, trust departments, and public agencies. To become a Residential Member (RM) of the Appraisal Institute requires 1-2 years of course work, examinations, and experience. Appraisers with the RM designation are restricted to estimating the market value of 1-4 unit family dwellings. To become a Senior Real Property Appraiser (SRPA) in the Society of Real Estate Appraisers requires 5-10 years of course work, numerous examinations, and many examples of appraisal work on all types of property. The SRPA designation is newer than MAI and not yet as widely recognized. Many appraisers were certified by both MAI and SRPA. To become a Senior Residential Appraiser (SRA) in the Society of Real Estate Appraisers requires 1-2 years of course work, examinations, and experience. Appraisers with the SRA designation are restricted to estimating the market value of 1-4 unit family dwellings. The SRA designation is similar to RM but older and more widely recognized. To become a Counselor of Real Estate (CRE) in the American Society of Real Estate Counselors is by invitation only after extensive investigation into experience, expertise, ethical reputation. In 1979, this was an elite group of only 466 members in the United States.

A questionnaire was prepared to obtain information on the contribution of forest quality to the market value of mountain property, in the opinion of appraisers. While the questionnaire was long, with 53 questions, it was designed and pretested for clarity and ease of answering. The questionnaire was designed to allow interviews to be completed in 45-60 minutes in order to minimize inconvenience, and to avoid respondent fatigue and lapse of concentration. See the appendix to this report for a copy of the questionnaire.

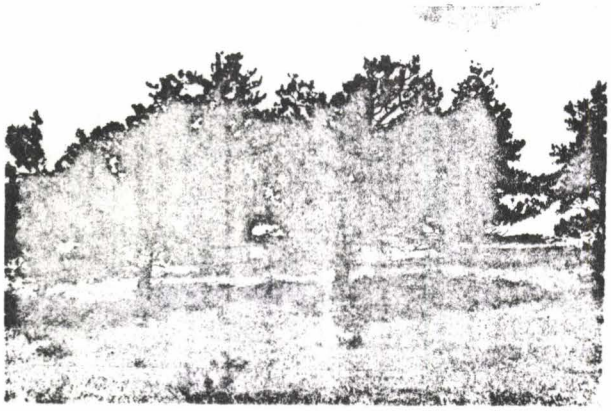
Sample size was determined by standard statistical practice to obtain results within the 90 percent level of statistical significance. For example, each of the 21 respondents provided four observations of the contribution of trees to the value of mountain property contingent on changes in tree numbers from zero to 10, 40, 100, and 275 trees per acre. Thus, a total of 84 observations were available for the variables of primary interest which was sufficient for significant statistical analysis.

Figure 2 shows black-and-white reproductions of five pictures of ponderosa pine forest with 0-300 trees per acre six inches dbh or more. Identical color pictures were shown each appraiser interviewed along with color pictures of visible mountain pine beetle damage and large specimen trees. They were selected from an inventory of over 200 exposures taken of ponderosa pine forest in the Front Range of Colorado. The photos represent a reasonable visual depiction of the range of forest quality in the study area, with a minimum of variation in other attributes of environmental quality such as rock outcroppings, ground cover, and sky. Appraisers were asked to assume that the photos were identical except for variation in forest quality. The interviewer identified the number of trees per acre in the photos and the average distance between trees. For example, the third picture was identified as having 40 trees per acre by actual count at the site where the photo was taken and trees an average of 30 feet apart. The fourth picture had 100 trees per acre by actual count 20 feet apart. The fifth picture has 250-300 trees per acre about 10 feet apart. This use of color photos conforms with recommendations of an interagency committee of the U.S. government [U.S. Water Resources Council, 1979] for studies of the economic value of changes in environmental quality.



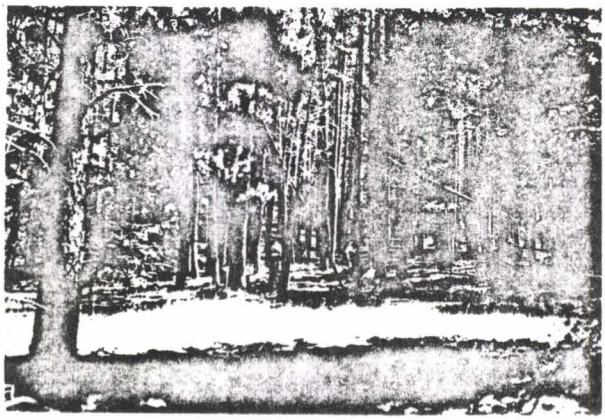
No Trees

10 Trees per Acre



40 Trees per Acre

100 Trees per Acre



250-300 Trees per Acre

Figure 2. Five Levels of Forest Quality, Front Range of the Rocky Mountains, Colorado 1980.

## IMPORTANCE OF TREES

Table 4 shows the importance of trees to the market value of mountain property in the opinion of real estate appraisers. Appraisers rated the importance of trees on mountain property, on adjacent property, and in the far view. The tastes and preferences of purchasers of mountain real estate for trees were rated on a 5-point scale with: (1) extremely important, (2) very important, (3) moderately important, (4) somewhat important, and (5) not important. Average scores are shown along with the standard deviations and the proportion with no opinion. Mean scores are shown as are standard deviations.

There was some difference of opinion among appraisers. However, 90-95 percent considered trees on the property, on adjacent property, and in the far view important determinants of the market value of mountain property. Importance declined with distance. Seventy-one percent considered trees on the property very important, compared to 48 percent on adjoining property, and 19 percent in the far view.

Table 5 shows the importance of trees relative to other attributes of the quality of mountain property in the opinion of real estate appraisers. Appraisers rated the importance of trees relative to rock outcroppings, topography, view of the mountains, and nearness to streams and lakes. The relative importance of trees compared to each of these attributes of landscapes quality was rated on a 5-point scale, with (1) much more important, (2) more important, (3) same importance, (4) less important, and (5) much less important. Average scores are shown along with the standard deviation and proportion with no opinion.

There was considerable variation in the opinion of appraisers as to the relative importance of trees. Overall, they rated trees as equal to or more

Table 4. Importance of Trees to Market Value of Mountain Property, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Location of Trees | Importance of Trees, Percent Reporting | | | | | | Average Score | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| | No Response (0) | Extremely Important (1) | Very Important (2) | Moderately Important (3) | Somewhat Important (4) | Not Important (5) | | |
| Importance of Trees on the Property | | 9.5 | 61.9 | 19.0 | 4.8 | 4.8 | 2.33 | 0.91 |
| Importance of Trees on Adjoining Property | | 0.0 | 47.6 | 38.1 | 4.8 | 9.5 | 2.76 | 0.94 |
| Importance of Trees in the Far View | | 0.0 | 19.0 | 42.9 | 33.3 | 4.8 | 3.24 | 0.83 |

Table 5. Importance of Trees Relative to Other Aspects of Landscape Quality, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Other Aspects of Landscape Quality | Percent of Sample Reporting Trees as | | | | | | Average Score | Standard Deviation |
|---|---|---|---|---|---|---|---|---|
| | No Response (0) | Much More Important (1) | More Important (2) | Same Importance (3) | Less Important (4) | Much Less Important (5) | | |
| Importance of Trees Relative to Rock Outcroppings | 4.8 | 9.5 | 42.9 | 33.3 | 9.5 | 0.0 | 2.33 | 0.97 |
| Importance of Trees Relative to Nearness to Streams and Lakes | 4.8 | 0.0 | 19.0 | 23.8 | 47.6 | 4.8 | 3.24 | 1.14 |
| Importance of Trees Relative to Topography | 9.5 | 0.0 | 42.9 | 28.6 | 19.0 | 0.0 | 2.48 | 1.12 |
| Importance of Trees Relative to Rocky Mountain View | 4.8 | 4.8 | 19.0 | 28.6 | 42.9 | 0.0 | 3.00 | 1.14 |

important than rock outcroppings and topography, but less important relative to view of the mountains and nearness to streams and lakes. The table shows that 53.4 percent of the appraisers rated trees more important than rock outcroppings, and 42.9 percent more important than topography. This compared to 23.6 percent who rated trees more important than the view of the mountains, and 19.0 percent more important than nearness to streams and lakes. The table shows that 52.4 percent rated trees less important than nearness to streams and lakes, and 42.9 percent less important than view of the mountains.

## NUMBER OF TREES ON PROPERTY

Figures 3-4 and Table 6 show the effect of live trees six inches dbh or more on the market value of improved and unimproved mountain property. It was estimated that value of trees per acre would decrease by 0.14 percent with a one percent decrease in the number of trees on improved property, compared to 0.15 percent on unimproved property. These average or arc elasticities of tree values with respect to number of trees on mountain property were calculated in the range of 1-15 percent decrease from 106 trees per acre, all other variables unchanged. This represents the effect of mountain pine beetle infestations which reduces the number of trees on residential mountain property. The following section of this report will present results with respect to the number of trees on adjoining property.

Ordinary least squares statistical methods were used to estimate the relationship of tree values to the number of trees and other social economic variables. The dependent variable was the contribution of trees to the market value of mountain property. The sample of 21 real estate appraisers reported the maximum market value of improved and unimproved mountain property contingent on changes in the number of trees six inches dbh or more. Number of trees was illustrated by four color photos of low, medium, high number of trees per acre. This resulted in a total of 84 observations of the relationship between market value and number of trees, which proved sufficient for statistically significant analysis. The proportion of the variation in the market value of trees explained by the independent variables included in the equations was .31 and .34 as measured by $R^2$ adjusted for degrees of freedom. All regression coefficients were significantly different from zero at the 0.00 to 0.12 level. The overall equations were statistically significant at the 0.01 level as indicated by an F

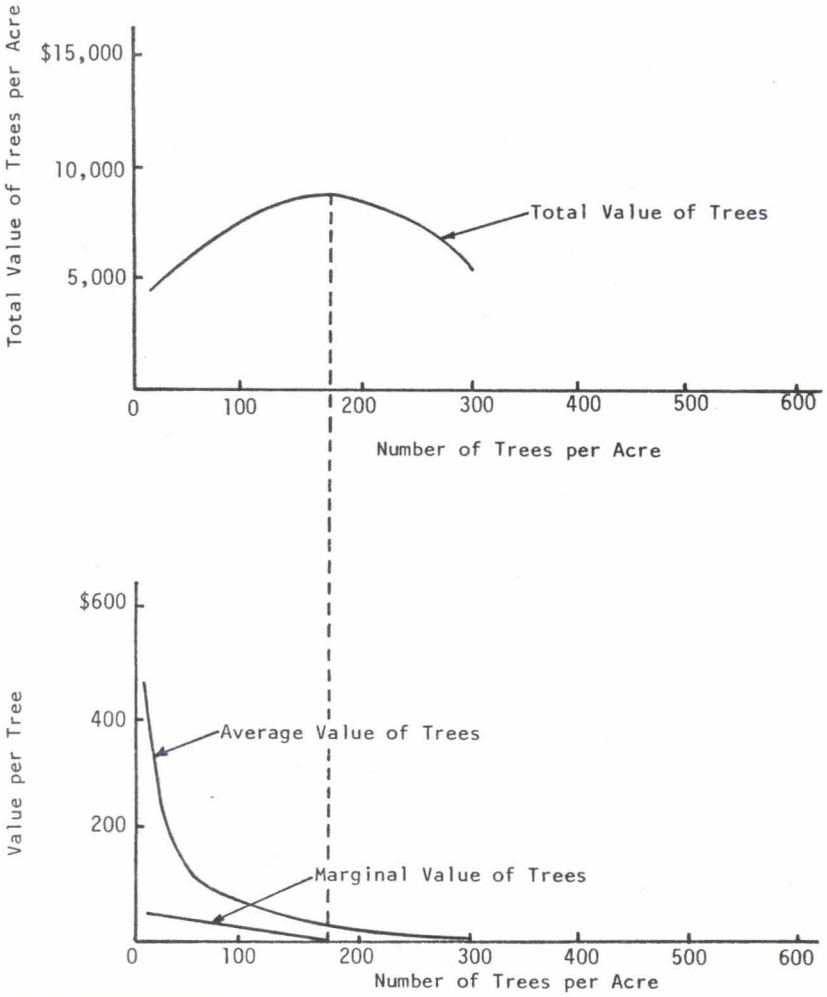



Figure 3. Total, Average, and Marginal Market Value of Trees on Improved One-Acre Tracts in the Opinion of Certified Real Estate Appraisers, Front Range, Colorado, 1980.

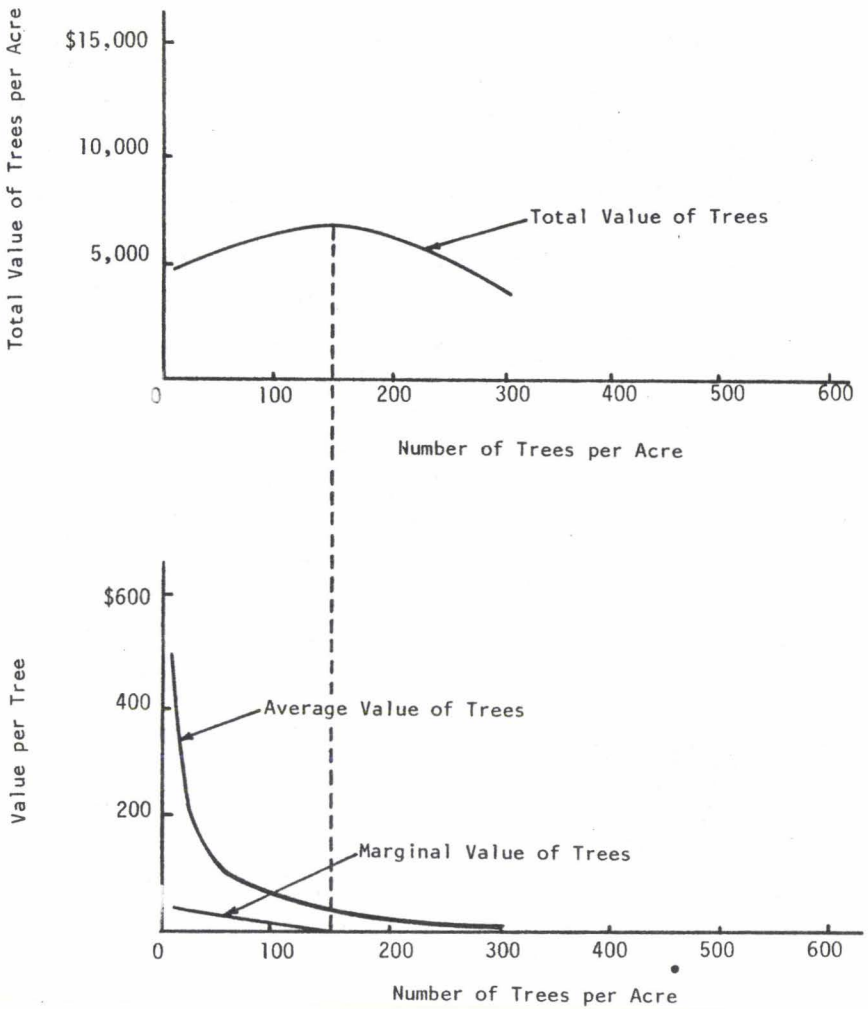



Figure 4. Total, Average and Marginal Market Value of Trees on Unimproved One-Acre Tracts in the Opinion of Certified Real Estate Appraisers, Front Range, Colorado, 1980.

Table 6. Total, Average and Marginal Value of Trees Six Inches dbh or More on Improved and Unimproved One Acre Tracts in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Number of Trees Per Acre | Improved | | | Unimproved | | |
|---|---|---|---|---|---|---|
| | Total Value | Average Value | Marginal Value | Total Value | Average Value | Marginal Value |
| 10 | $5,460 | $545.96 | $37.84 | $4,743 | $474.28 | $28.71 |
| 25 | 5,991 | 239.65 | 33.04 | 5,149 | 205.95 | 25.41 |
| 50 | 6,717 | 134.34 | 25.04 | 5,715 | 114.30 | 19.91 |
| 75 | 7,243 | 96.57 | 17.04 | 6,144 | 81.92 | 14.41 |
| 100 | 7,569 | 75.69 | 9.04 | 6,436 | 64.36 | 8.91 |
| 125 | 7,695 | 61.56 | 1.04 | 6,590 | 52.72 | 3.41 |
| 150 | 7,621 | 50.81 | -6.96 | 6,606 | 44.04 | -2.09 |
| 175 | 7,347 | 41.98 | -14.96 | 6,485 | 37.06 | -7.59 |
| 200 | 6,873 | 34.37 | -22.96 | 6,227 | 31.13 | -13.09 |
| 225 | 6,199 | 27.55 | -30.96 | 5,831 | 25.91 | -18.59 |
| 250 | 5,325 | 21.30 | -38.96 | 5,297 | 21.19 | -24.09 |
| 275 | 4,251 | 15.46 | -46.96 | 4,626 | 16.82 | -29.59 |
| 300 | 2,977 | 9.92 | -54.96 | 3,818 | 12.73 | -35.09 |
| 325 | 1,503 | 4.63 | | 2,872 | 8.84 | |
| 350 | -171 | -0.49 | | 1,788 | 5.11 | |
| 375 | | | | 567 | 1.51 | |
| 400 | | | | -791 | -1.98 | |

significance of 6.33 and 11.15. Alternative forms of the equation were tried including linear, quadratic and logarithmic forms, with the quadratic model providing the best fit of the relationship of interest. The usual tests of the assumptions of the regression model including multicolinearity and heteroscedasticity revealed little or no significant effects on the study results.

The stepwise regression technique was used to estimate the coefficients and the constant of each model. The general equations were condensed to show the relationship between the two variables of interest. All independent variables other than number of trees and number of trees squared were multiplied by their means and added to the constant. The following reduced functions were obtained for the relationship between the number of trees per acre and the market value (in $100s) of improved and unimproved mountain property:

$$\text{Market value of trees on improved property} = 50.6517 + 0.4107\text{TREES} - 0.0016\text{TREES}^2$$

$$\text{Market value of trees on unimproved property} = 44.4471 + 0.3091\text{TREES} - 0.0011\text{TREES}^2$$

As expected, these equations indicate that trees contribute more value to improved property than to unimproved. With otherwise identical conditions, market value of improved property increased by about $41 per tree and declined by $0.16 per additional tree squared; while market value of unimproved property increased by approximately $31 per additional tree and declined by $0.11 per additional tree squared. The resulting functions provide a reasonable representation of the effect of trees on property values in the mid-range which is the relevant area of decision making. The functions should not be taken to the extreme of very low or very high number of trees. The latter represents an extrapolation as no observations were taken beyond 275 trees per acre.

Figures 3-4 and Table 6 show that the resulting total value functions were inverted U-shaped. The total value of trees on improved mountain property increased at a decreasing rate from $5,460 with per acre with 10 trees to $6,717 per acre with 50 trees, $7,569 per acre with 100 trees, to a maximum of $7,697 per acre with 128 trees. Thereafter, the contribution of trees to the market value of improved property fell with additional trees per acre. By composition, the total value of trees on unimproved property increased at a decreasing rate from $4,743 per acre with 10 trees to $5,715 per acre with 50 trees, $6,436 per acre with 100 trees to a maximum of $6,616 per acre with 140 trees. Thereafter, market value of unimproved property fell with additional trees per acre. Thus, trees contribute nearly $717 per acre more value to improved than to unimproved property with 10 trees per acre, $1,002 more value with 50 trees per acre, $1,133 more with 100 trees per acre, and $1,081 more at maximum values.

The marginal value of additional trees on improved mountain property decreased at nearly a constant rate from $38 per tree with 10 trees to $25 per acre with 50 trees, $9 with 100 trees and zero with 128 trees. The marginal value of additional trees on unimproved property decreased from $29 per acre with 10 trees to $20 per acre with 50 trees, $9 per acre with 100 trees and zero with 140 trees.

Other variables shift the vertical intercept of the function relating value of trees to number of trees per acre. Table 7 shows the variables which were significantly related to the value of trees. Those which were positively associated with the value of trees include: importance of trees on the property, on adjacent property, and in the far view; preference for trees relative to rocky mountain view, and nearness to streams and lakes. Variables that were negatively

Table 7. Ordinary Least Square Equation Estimates of the Market Value of Trees Six Inches dbh or More on Improved and Unimproved One Acre Tracts in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Independent Variables | Regression Coefficients[a] | |
|---|---|---|
| | Improved | Unimproved |
| Number of Trees on One Acre Tract | .4104<br>(1.66) | .3091<br>(1.61) |
| Number of Trees on One Acre Tract, squared | -.0016<br>(-1.83) | -.0011<br>(-1.65) |
| Importance of Trees on Property, 5-point scale | -18.1111<br>(-3.08) | |
| Importance of Trees Relative to Rocky Mountain View, 5-point scale | -12.1261<br>(-2.61) | |
| Years of Experience as Mountain Real Estate Appraiser | -1.9521<br>(-2.37) | -2.0332<br>(-3.86) |
| Importance of Trees in the Far View, 5-point scale | -15.7630<br>(-2.23) | |
| Years of Experience as Real Estate Appraiser | -1.0816<br>(-1.85) | |
| Importance of Trees on Adjoining Property, 5-point scale | | -22.3493<br>(-5.33) |
| Importance of Trees Relative to Nearness to Streams and Lakes, 5-point scale | | -5.4733<br>(-1.56) |
| Constant | 220.7212<br>(6.68) | 148.1015<br>(8.02) |
| Adjusted $R^2$ | .31 | .34 |
| F Significance | 6.33 | 11.15 |
| Number of Observations | 84 | 84 |

a. Numbers in parentheses below each coefficient represent student t-ratios for the null hypothesis. All variables are significant at the .00 to .12 confidence levels.

associated with the value of trees were years of experience as real estate appraiser and as mountain real estate appraiser. Other variables which were tried and found not significantly associated with the value of trees were: importance of trees relative to rock outcroppings and to topography.

Other important variables were controlled independent of the regression analysis. The market value questions assumed that the mountain properties shown in the color pictures were exactly the same except for number of trees. Ponderosa pine trees were in a scattered arrangement. Size of lot was held constant at one acre, roughly 200 x 200 feet. Topography was specified as gently sloping land with little or no rolls. Access was by public road in front of the property. All schools were equally close and lots were in the same subdivision in the vicinity of Estes Park, Colorado, located in the northern Front Range of Colorado adjacent to Rocky Mountain National Park. Available utilities included electricity, sewer and water in front of the lot. The house and other improvements were valued at $80,000 and included 1,500 to 2,000 square feet of living space, two baths, two-car garage, fireplace, three bedrooms, and a family room. Land value was $20,000 for a one-acre tract with no trees. Both house and lot values were consistent with values reported in the study area.

Apparently, younger appraisers who were trained and received certification in recent years were more sensitive to the value of trees on mountain property than their older peers. The market value of trees on improved mountain property increased by $108 per acre with each one year decrease in number of years employed in mountain real estate appraisal was associated with an increase of $195 per acre in the market value of trees on improved mountain property and an increase of $203 per acre on unimproved mountain property.

Tastes and preferences for trees also were associated with the appraised market value of trees on Front Range mountain property. The value of trees on improved property increased by $1,811 with one unit increase in the importance of trees on mountain property, based on a five-point scale with one most important and five least. This compares to an increase of $2,235 per acre in the value of unimproved lots with a one unit increase in the importance of trees on adjoining property, and an increase of $1,576 per acre with a one unit increase in the importance of trees in the far view from improved mountain property. The value of trees on unimproved mountain property increased by $547 per acre with one unit increase in the preference for trees relative to nearness to streams and lakes. The value of trees on improved mountain property increased by $1,213 per acre with one unit increase in the preference for trees relative to view of the mountains.

## TREES ON ADJACENT PROPERTY

Figure 5 and Table 8 show the change in the contribution of trees to the market value of improved mountain property with change in the number of live trees six inches dbh or more on adjacent property in the near view. It was estimated that the contribution of trees to the value of mountain property would decrease by 0.12 percent with a one percent decrease in the number of trees on adjacent property. This average or arc elasticity of tree value with respect to number of trees on adjacent property was calculated in the range of 1-15 percent decrease from 106 trees per acre on adjacent property, all other variables unchanged. This represents the external cost of mountain pine beetle infestation which reduces the number of trees in the neighborhood of improved mountain property.

Ordinary least squares statistical methods were used to estimate the relationship of the market value of improved mountain property to the number of trees on adjacent property and other social and economic variables. The dependent variable was the change in the contribution of to the market value of the highest valued improved mountain property. The sample of 21 appraisers reported the maximum market value of one-acre tracts of improved mountain property contingent on changes in the number of trees six inches dbh or more on adjacent property in the near view. Number of trees was illustrated by five color photos of low, medium and high trees per acre. This resulted in a total of 105 observations of the relationship between property values and trees on adjacent property, which was sufficient for statistically significant analysis. The proportion of variation in the value explained by the independent variables included in the equation was .24 as measured by $R^2$ adjusted for degrees of freedom. All regression coefficients

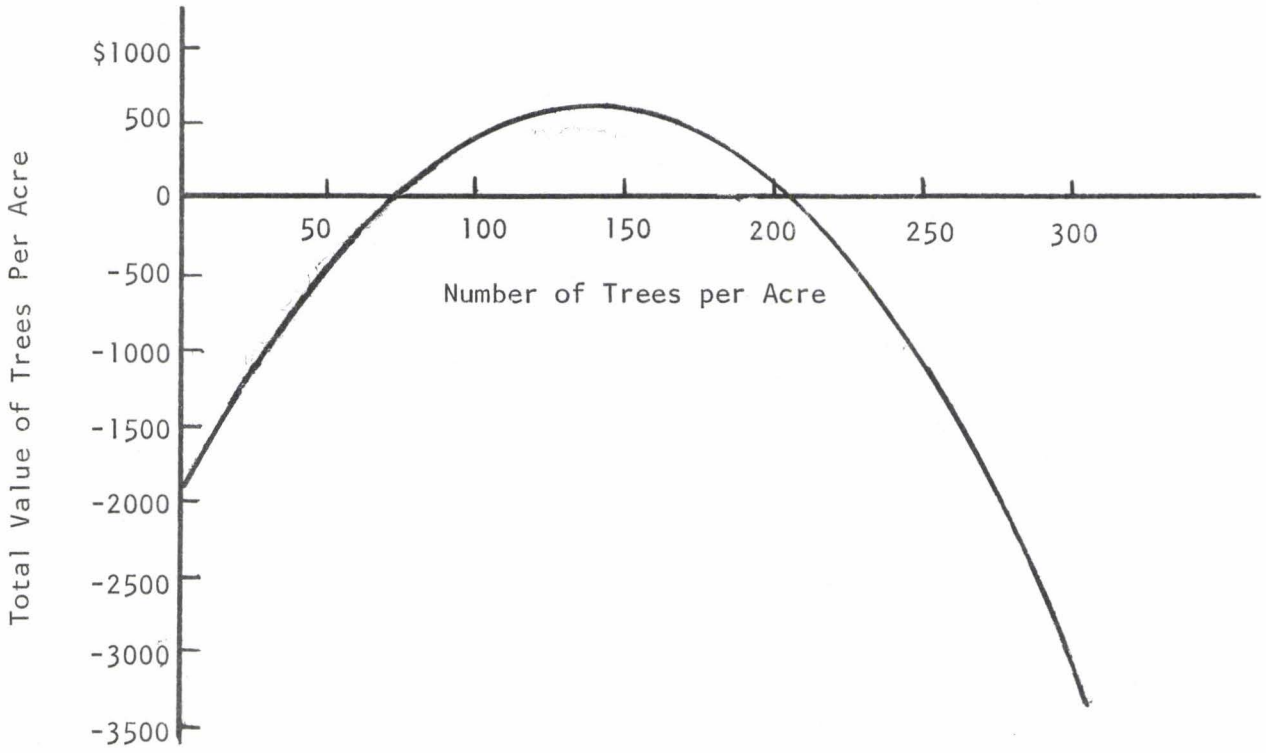



Figure 5. Changes in Market Value of Trees on Improved One-Acre Tracts Contingent on the Number of Trees per Acre Six Inches dbh or more on Adjacent Property in the Near View, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

Table 8. Change in Market Value of Trees on Improved One-Acre Tracts Contingent on the Number of Trees per Acre Six Inches dbh or More on Adjacent Property in the Near View, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Number of Trees Per Acre | Change in Market Value of Trees on Property |
|---|---|
| 0 | -$2,061 |
| 10 | -$1,689 |
| 25 | - 1,184 |
| 40 | - 742 |
| 50 | - 482 |
| 75 | 45 |
| 100 | 397 |
| 125 | 574 |
| 150 | 576 |
| 175 | 403 |
| 200 | 55 |
| 225 | - 468 |
| 250 | - 1,166 |
| 275 | - 2,039 |
| 300 | - 3,087 |

were significantly different from zero at the 0.01 confidence level. The overall equation was statistically significant at the 0.01 level as indicated by an F significance of 8.75. Alternative forms of the equation were tried including linear, quadratic, and logarithmic forms, with the quadratic model providing the best fit of the relationship of interest. The usual tests of the assumptions of the regression model revealed little or no significant effects on the study results.

The stepwise multiple regression technique was used to estimate the coefficients and the constant of the model. The general equation was condensed to show the relationship between the two variables of interest. All independent variables other than number of trees on adjacent property and number of trees squared were multiplied by their means and added to the constant. The following reduced function was obtained for the relationship between the number of trees on adjacent property and the contribution of trees to the value (in $100s) of improved mountain property:

$$\begin{array}{l}\text{Change in the}\\ \text{contribution of}\\ \text{trees to the value}\\ \text{of improved property}\end{array} = -20.6097 + 0.3858\text{TREES} - 0.0014\text{TREES}^2$$

This equation indicates that the contribution of trees to the value of improved mountain property falls by $2,061 per acre when there are no trees on adjacent property. With otherwise identical conditions, the contribution of trees on adjacent property to the value of mountain property increases by nearly $39 per additional tree on adjacent property and decreases by $0.14 per additional tree squared. The resulting function provides a reasonable representation of the effect of adjacent trees on values in the lower to mid-range which is the relevant area of decision making. The function should not be taken to the extreme

of very large numbers of trees which represents an extrapolation as no observations were taken beyond 275 trees per acre.

Figure 5 and Table 8 show that the resulting total value function was inverted U-shaped. The total contribution of trees to the market value of improved mountain property would fall by $1,689 per acre with 10 trees per acre on adjacent property, by $482 per acre with 50 trees per acre, and would have no effect with approximately 73 trees per acre on adjacent property. The total contribution of trees to the value of improved mountain property would increase by $397 per acre with 100 trees per acre on adjacent property, and would reach a maximum of $597 per acre with 138 trees on adjacent property. Thereafter, the total contribution of trees to the value of improved mountain property would decline with additional trees on adjacent property. Indications are that beyond 203 trees per acre on adjacent property, additional trees would reduce that contribution of trees to the value of improved mountain property, although this is an extrapolation beyond 275 trees per acre.

Other social economic variables shift the vertical intercept of the function relation relating the contribution of trees to improved property values and number of trees on adjacent property. Table 9 shows the variables which were significantly related to the change in value of trees. Positively related was preference for trees relative to rock outcroppings. Negatively related was years of experience as a real estate appraiser. Other variables which were tried and found not significantly associated with tree values include: years of experience as a mountain real estate appraiser; importance of trees on the property, on adjacent property, and in the near view; preference for trees relative to topography, view of the mountain and nearness to streams and lakes.

Table 9. Ordinary Least-Square Equation Estimates of the Market Value of Trees on Improved One-Acre Tracts Contingent on Changes in the Number of Trees Six Inches dbh or More on Adjacent Property in the Near View in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Independent Variables | Regression Coefficients[a] |
|---|---|
| Number of Trees per Acre[b] | 0.3858<br>(3.48) |
| Number of Trees per Acre Squared | -0.0014<br>(-3.33) |
| Years of Experience as a Real Estate Appraiser | -0.5805<br>(-2.60) |
| Importance of Trees on the Property Relative to Rock Outcroppings, 5-point scale | -4.8878<br>(-2.71) |

Adjusted $R^2$ = .24

F Significance = 8.75

Number of Observations = 105

a. Numbers in parentheses below each coefficient represent student t-ratios for the null hypothesis. All variables are significant at the 99 percent confidence level.

b. The change in value was zero for: nine appraisers with no trees, sixteen appraisers with 10 trees, eighteen appraisers with 40 trees, fifteen appraisers with 100 trees, and twelve appraisers with 250-300 trees on adjacent property.

Other important variables were controlled independent of the regression analysis. The market value questions assumed that the mountain properties shown in the color pictures were exactly the same except for the number of trees. Ponderosa pine trees were in a scattered arrangement. The size of lot was held constant at one acre, roughly 200 x 200 feet. Topography was specified as gently sloping land with little or no rolls. Access was by public road in front of the property. All schools were equally close and lots were in the same subdivision in the vicinity of Estes Park, Colorado, located in the northern Front Range of Colorado adjacent to Rocky Mountain National Park. Available utilities included electricity, sewer and water in front of the lot. The house and other improvements were valued at $80,000 and included 1,500 to 2,000 square feet of living space, two baths, two-car garage, fireplace, three bedrooms, and a family room. Land value was $20,000 for a one-acre tract with no trees. Both house and lot values were consistent with values reported in the study area.

Apparently, younger appraisers who were trained and received certification in recent years placed a higher value on trees adjacent to mountain property than their older peers. The contribution of trees to the market value of improved mountain property increased by $58 per acre with each one year decrease in number of years employed in the real estate appraisal work.

Relative preference for trees also was associated with the effect of adjacent trees on the value of Front Range mountain property. The effect of trees on adjacent property increased by $489 per acre with one unit increase in the preference for trees relative to rock outcroppings based on a five-point scale with one most and five least importance of trees.

## SIZE OF TREES

Figure 6 and Table 10 show the effect of size of trees on the market value of improved and unimproved mountain property. It was estimated that market value of mountain property would fall by 0.53 percent with a one percent decrease in the size of trees on improved property, compared to 0.54 percent with a one percent decrease in the size of trees on unimproved property. This average or arc elasticity of tree values with respect to size was based on observations in the range of 3-12 inches dbh. This represents the effect of mountain pine beetle infestation which reduces the average size of surviving trees. In a later section of this report the statistical analysis of the effect of tree size on the value of trees will be used to show that with reforestation after an insect infestation, value of trees would rise over the growth cycle of ponderosa pine. This is an important consideration when calculating the present value of benefits from a mountain pine beetle control program over a planning period of 50 to 100 years.

Ordinary least squares statistical methods were used to estimate the relationship of property value to the size of trees and other social and economic variables. The dependent variable was the contribution of tree size to the market value of one-acre tracts. The sample of 21 appraisers reported the maximum market value of improved and unimproved mountain property contingent on changes in size of tree from six inches dbh to three inches dbh and to 12 inches dbh. Size of trees was illustrated by color photos. This resulted in a total of 63 observations of the relationship between tree values and size, which was sufficient for statistically significant analysis. The proportion of variation in the value of trees explained by the independent variables included in the equations

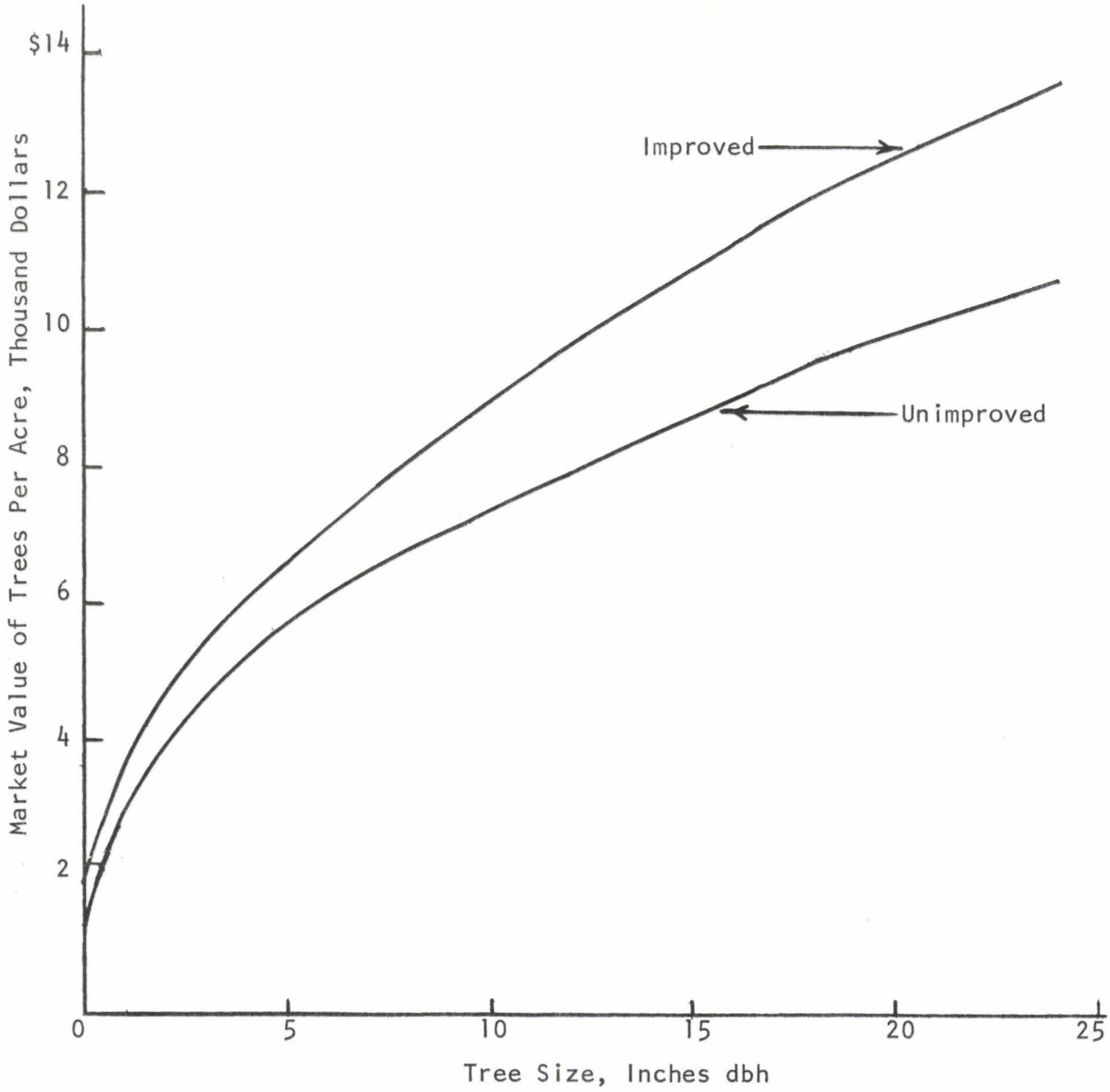



Figure 6. Market Value of Trees on Improved and Unimproved One-Acre Tracts Contingent on Changes in the Size of Trees, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

Table 10. Market Value of Trees on Improved and Unimproved One Acre Tracts Contingent on Changes in the Size of Trees, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Size of Trees, Inches dbh | Market Value of Trees per Acre[a] | |
|---|---|---|
| | Improved | Unimproved |
| 1 | $ 3,750 | $ 3,260 |
| 2 | 4,722 | 4,108 |
| 3 | 5,488 | 4,744 |
| 4 | 6,145 | 5,273 |
| 5 | 6,731 | 5,734 |
| 6 | 7,266 | 6,147 |
| 7 | 7,762 | 6,524 |
| 8 | 8,228 | 6,873 |
| 9 | 8,667 | 7,199 |
| 10 | 9,085 | 7,506 |
| 11 | 9,485 | 7,797 |
| 12 | 9,868 | 8,074 |
| 15 | 10,940 | 8,836 |
| 18 | 11,918 | 9,519 |
| 21 | 12,826 | 10,143 |
| 24 | 13,676 | 10,721 |

a. From equations shown as Table forced through the means of the market value of trees.

was .56 and .63 as measured by $R^2$ adjusted for degrees of freedom. All regression coefficients were significantly different from zero at the 0.00 to 0.05 confidence levels. The overall equations were statistically significant at the 0.01 level as indicated by F significance levels of 16.96 to 26.87. Alternative forms of the equations were tried including linear, quadratic and logarithmic forms, with the semi-logarithmic and double-logarithmic models providing the best fit of the relationship of interest. The usual tests of the assumptions of the regression model revealed little or no significant effects of the study results.

The stepwise multiple regression technique was used to estimate the coefficients and the constant for each model. The general equations were condensed to show the relationship between the two variables of interest. All independent variables other than the log of tree size were multiplied by their means and added to the constant. The following power functions were obtained the relationship between tree size and the value of trees (in 100s) on improved and unimproved mountain property:

$$\text{Market value of trees on improved property} = 20.9785\,(\text{SIZE})^{.5494}$$

$$\text{Market value of trees on unimproved property} = 22.6894\,(\text{SIZE})^{.4581}$$

As expected, these equations indicate that tree size contributes more value to improved property than to unimproved. With otherwise identical conditions, the value of trees on improved mountain property increased by nearly .55 percent with one percent increase in tree size, compared to nearly .46 on unimproved property. The resulting functions provide a reasonable representation of the effect of tree zone on property values in the mid-range of size which is the most

relevant area of decision making. However, the functions should not be taken to the extreme of very low or high tree size, which represents an extrapolation as no observations were taken below 3 inches or above 12 inches dbh.

Figure 6 and Table 10 show that the resulting total value functions rise at an increasing and then decreasing rate over the range of size from 1 to 24 inches dbh. The total value of trees on improved mountain property increased from $5,488 per acre with trees three inches dbh, to $7,266 per acre with trees six inches dbh, to $9,868 with trees 12 inches dbh, and to $13,676 with trees 24 inches dbh. This compared to the value of trees on unimproved mountain property which increased from $4,744 per acre with trees three inches dbh, to $6,147 per acre with trees six inches dbh, to $8,074 per acre with trees 12 inches dbh, and to $10,721 per acre with trees 24 inches dbh. Thus, tree size contributed nearly $744 more value to improved than to unimproved property with trees 3 inches dbh, $1,119 more value with trees 6 inches dbh, $1,794 more value with trees 12 inches dbh, and $2,955 more value with trees 24 inches dbh. The average size of ponderosa pine in the cut-over Front Range forests was 9-12 inches dbh, and few mature trees of 20-24 inches dbh remain.

Other variables shift the vertical intercept of the functions relating property value to tree size. Table 11 shows the social economic variables which were significantly related to property values. Variables which were positively associated with property values include: years of experience as an appraiser and as an appraiser of mountain property; preference variables including the importance of trees on mountain property, on adjoining property, and importance of trees relative to view of the mountains, and nearness to streams and lakes. Variables which were tried and found not significantly associated with the tree size value functions include: preference for trees in the far view, and importance

Table 11. Ordinary Least-Square Equation Estimates of the Market Value of Trees on Improved and Unimproved One-Acre Tracts Contingent on Changes in the Size of Trees, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Independent Variables | Regression Coefficients[a] | |
|---|---|---|
| | Improved | Unimproved |
| Log of Tree Size, Inches dbh[b] | 0.5498<br>(3.42) | 0.4581<br>(3.73) |
| Years of Experience as Mountain Real Estate Appraisor | 0.0592<br>(3.42) | 0.0401<br>(-4.2) |
| Importance of Trees on Adjoining Property | -0.3473<br>(-2.51) | -0.5988<br>(-7.89) |
| Importance of Trees Relative to Proximity of Property to Stream and Lakes, 5-point scale | | -0.2097<br>(-3.31) |
| Importance of Trees on Property, 5-point scale | -0.3187<br>(-2.19) | |
| Importance of Trees Relative to Rocky Mountain View, 5-point scale | -0.2234<br>(-2.61) | |
| Constant | 6.1215<br>(12.47) | 5.9428<br>(15.63) |
| Adjusted $R^2$ | .56 | .63 |
| F Significance | 16.96 | 26.87 |
| Number of Observations | 63 | 63 |

a. Numbers in parentheses below each coefficient represent student t-ratios for the null hypothesis. All variables are significant at the 95 percent confidence level or above.

b. It should be noted that the change in value of trees 3 inches dbh on improved property was zero for eight appraisers and on unimproved property zero for seven appraisers. The mode of change in value of trees 12 inches dbh on improved and unimproved property was zero for 14 appraisers.

of trees relative to rock outcroppings.

Other important variables were controlled independent of the regression analysis. The market value questions assumed that the mountain properties shown in the color pictures were exactly the same except for the size of trees. Ponderosa pine trees were in a scattered arrangement. The most preferred number of trees per acre, usually 100 trees, was specified by each individual appraiser. The size of lot was held constant at one acre, roughly 200 x 200 feet. Topography was specified as gently sloping land with little or no rolls. Access was by public road in front of the property. All schools were equally close and lots were in the same subdivision in the vicinity of Estes Park, Colorado, located in the northern Front Range of Colorado adjacent to Rocky Mountain National Park. Available utilities included electricity, sewer and water in front of the lot. The house was valued at $80,000 and included 1,500 to 2,000 square feet of living space, two baths, two-car garage, fireplace, three bedrooms, and a family room. Land value was $20,000 for a one-acre tract. Both house and lot values were consistent with values reported in the study area.

Younger appraisers who were trained and received certification in recent years were more sensitive to size of trees on mountain property than their older peers. The intercept of the size of tree value function for improved mountain property per acre increased by 5.9 percent with each one year decrease in number of years employed in mountain real estate appraisal work. Each one year decrease in number of years employed in mountain real estate appraisal was associated with an increase of 4.0 percent in the market value of trees per acre of unimproved mountain property.

Tastes and preferences for trees also were associated with the appraised market value of tree size on Front Range mountain property. The intercept of the size of tree value function on improved property increased by 31.9 percent with one unit increase in the importance of trees on mountain property, based on a five-point scale with one most important and five least. This compares to an increase of 34.7 percent in the value of improved property per acre with a one unit increase in the importance of trees on adjoining property, and an increase of 59.9 percent in the value of trees on unimproved lots with a one unit increase in the importance of trees on adjoining property. The value of trees on unimproved mountain property increased 21.0 percent with one unit increase in the preference for trees relative to nearness to streams and lakes. The value of trees on improved mountain property increased by 22.3 percent with one unit increase in the preference for trees relative to view of the mountains.

## OTHER ASPECTS OF FOREST QUALITY

Appraisers also estimated the change in market value of trees on improved and unimproved mountain property with changes in several other important attributes of forest quality. These included: expectation of a future outbreak of severe insect infestation; visible insect damage to trees on the property, on adjacent property in the near view, and in the far view; insect damage to large specimen trees 24 inches dbh or more; change in species of trees; and distribution of trees on the property.

Attempts to test the statistical significance of variables associated with market value effects of these attributes of forest quality were unsuccessful owing to the small sample of 21 appraisers. Years of experience and preference variables were not significantly related to market value effects. However, the most important variables were controlled independent of the regression attempt. It was assumed that the mountain property was exactly the same except for the changes in forest quality. The size of lot was held constant at one acre, roughly 200 x 200 feet. Ponderosa pine trees were in a scattered arrangement. Topography was specified as gently sloping land with little or no rolls. Access was by public road in front of the property. All schools were equally close and lots were in the same subdivision in the vicinity of Estes Park, Colorado. Utilities included electricity, sewer and water available in front of the lot. The house was valued at $80,000 and included 1,500 to 2,000 feet of living space, two baths, two-car garage, fireplace, three bedrooms, and a family room. Land value was $20,000 consistent with values reported in the study areas.

Expectation of Insect Damage

Table 12 shows the effect of a general outbreak of severe insect infestation when forest entomologists predict that 50 percent of the trees on mountain property will be killed within five years. During the past decade, the market for mountain property reflected the probabilitiy of such a large loss in number of trees in several parts of the Front Range of the Rocky Mountains in Colorado. Expectation of future insect kill led to immediate discount of the present market value of both improved and unimproved mountain property in anticipation of future damage to forest quality.

Real estate appraisers on the Front Range reported that the market value of trees per acre would decrease by -0.94 percent with each one percent increase in expected insect kill of trees on improved mountain property. The average elasticity of tree values with respect to expected insect kill was calculated as -0.94 in the range of 1-50 percent of 106 trees six inches dbh or more per acre on improved mountain property, all other variables unchanged.

The effect of expected future insect kill was virtually identical on unimproved mountain property. Value of trees per acre would decrease by -0.92 percent with each one percent increase in expected insect kill of trees on unimproved mountain property. This suggests that a general outbreak of insect infestation would have a broad effect on the market value of all mountain property, both improved and unimproved, in the opinion of real estate appraisors.

Table 12. Change in the Market Value of Trees on Mountain Property if Forest Entomologists Predict that 50 Percent of Trees will be Killed by Insect Infestation Within Five Years, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Change in Expectations | Value of 106 Trees Per Acre Six Inches dbh or More | |
|---|---|---|
| | Improved | Unimproved |
| Without Expectation of Forest Insect Infestation | $9,571 (5,893)[c] | $8,071 (4,920) |
| With Expectation that 50 Percent of Trees will be Killed Within Five Years | $5,095 (4,067) | $4,381 (3,775) |
| Change in Value[a] | -$4,476 | -$3,690 |
| Percent Change | -46.77 | -45.72 |
| Elasticity[b] | - 0.94 | - 0.92 |

a. Three appraisers reported no change in improved property values, and seven reported no change in unimproved property values. Improved median value was $4,500 and mode $5,000 for seven appraisers. Unimproved median value was $3,000 and mode $5,000 for five appraisers.

b. Average elasticity calculated as percent change in value of trees divided by 50 percent change in number of live trees in five years.

c. Values in parentheses are standard deviations.

Visible Insect Damage

Table 13 shows the effect of visible insect damage to 15 percent of the trees on mountain property compared to trees on adjacent property and in the far view. Visible insect damage to ponderosa pine occurs during the second year after a mountain pine beetle attack when needles appear rust colored on dying trees. Visible insect damage to douglas fir occurs whenever spruce budworm infestation is present, causing discoloration and defoliation of newly grown needles and stinting of growth which seldom kills the trees.

Market value of trees per acre would decrease by a reported 2.48 percent with visible insect damage to one percent of the trees on improved mountain property. The average elasticity of tree values with respect to visible insect damage was calculated as -2.48 percent in the range of 1-15 percent of 100 trees per acre six inches dbh or more with insect damage on improved mountain property, all other variables unchanged. The effect of visible insect damage would be somewhat less on unimproved mountain property. Value of trees per acre would decrease by -2.06 percent with visible beetle damage to one percent of trees on unimproved mountain property, or by 0.42 percentage points less than for improved mountain property.

The effect of visible insect damage to adjacent property, in the near view, would be substantial although considerably less than in the case of visible insect damage to trees on the property. Values of trees per acre would decrease by -1.07 percent with visible insect damage to one percent of the trees on property adjacent to improved mountain property, or 1.85 percentage points less than the value loss on the property. The effect of visible insect damage on property

Table 13. Change in the Market Value of Trees with Visible Insect Damage to 15 Percent of Trees on Mountain Property, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| With and Without Visible Insect Damage | Value of 100 Trees Per Acre Six Inches dbh or More | |
|---|---|---|
| | Improved | Unimproved |
| Without Visible Insect Damage | $7,762 (5,798)[e] | $6,524 (4,241) |
| With 15 Percent Visible Insect Damage to Trees on the Property | $4,867 (4,881) | $4,510 (3,729) |
| Change in Value[a] | -$2,895 | -$2,014 |
| Percent Change | - 37.3 | - 30.87 |
| Elasticity[b] | - 2.48 | - 2.06 |
| With 15 Percent Visible Insect Damage to Trees on Adjacent Property, in the Near View | $6,510 (5,792) | $4,710 (3,716) |
| Change in Value[c] | -$1,252 | -$1,814 |
| Percent Change | - 16.1 | - 27.81 |
| Elasticity | - 1.07 | - 1.85 |
| With 15 Percent Visible Insect Damage to Trees in the Far View from the Property | $7,570 (6,059) | $5,895 (4,012) |
| Change in Value[d] | -$ 192 | -$ 629 |
| Percent Change | - 2.47 | - 9.64 |
| Elasticity | - 0.16 | - 0.64 |
| Total Effect with 15 Percent Visible Insect Damage to the Front Range Forest | $3,423 | $2,067 |
| Change in Value | -$4,339 | -$4,459 |
| Percent Change | - 55.9 | - 68.32 |
| Elasticity | - 3.73 | - 4.55 |

a. Median value was $2,500 for improved and $1,300 for unimproved; mode was zero for five appraisers, both improved and unimproved.

b. Average elasticity calculated as percent change in value of trees divided by 15 percent change in visible insect damage.

c. Median value was $500 for both improved and unimproved; mode was zero for eight appraisers.

d. Median value was zero for both improved and unimproved; mode was zero for 16 appraisers.

e. Values in parentheses are standard deviations.

adjacent to unimproved mountain property would be higher than the damage to improved property. Value of trees per acre on unimproved property would decrease by a reported -1.85 percent with visible insect infestation of trees on adjoining property, or 0.78 percent more damage than for improved property.

The effect of visible insect damage to trees in the far view would be much less than in the case of visible insect damage to trees on mountain property or on adjacent property. Market value of trees on improved mountain property would decrease by -0.16 percent with visible insect damage to one percent of trees in the far view from improved mountain property. The effect of visible insect damage in the far view from unimproved mountain property would be approximately four times the damage to improved mountain property. Value of trees per acre would decrease by a reported -0.64 percent with visible insect infestation of trees in the far view from unimproved mountain property.

The total effect of visible insect damage from general infestation of the Front Range forest would be the sum of effects on mountain property, adjacent property, and property in the far view. Market value of trees per acre on improved mountain property would decrease by a total of -3.73 percent with visible insect damage to one percent of the trees on the property, in the near view, and in the far view. Market value of trees per acre on unimproved mountain property would decrease even more or by -4.55 percent with visible insect damage to one percent of the trees on the property, in the near view, and in the far view.

Specimen Trees

Tables 14 and 15 show the effect of specimen trees 24 inches dbh or more on mountain property values. Forest insects such as the mountain pine beetle and spruce budworm frequently have attacked these large mature trees which are very scarce in the cutover forest on the Front Range of the Rocky Mountains. Once the dead specimen trees are removed, it is unlikely that most prospective buyers would be aware that an insect infestation ever occurred in the area. The fact remains, however, that in a subdivision where insect damage has occurred, the value of the trees would be significantly different from what it would have been in the absence of the insect damage. Thus, the market value of mountain property would be reduced with the loss of specimen trees to insect attack.

Real estate appraisers on the Front Range reported that the market value of trees per acre would decrease by 1.8 percent with the loss of one percent of the trees (1 specimen tree per acre) on improved mountain property. The average or arc elasticity of tree values with respect to specimen trees was calculated as 1.8 percent in the range of 1-5 percent of 106 trees per acre, with all other variables unchanged. It should be noted that this analysis assumes that the reduction in value from a loss of large specimen trees would equal the reported increase in the value from their presence or gain. The elasticity of tree values with respect to loss of specimen trees is shown along with their gain in Table 14.

The effect of specimen trees was somewhat more on unimproved mountain property. Value of trees per acre would decrease by 2.4 percent with each one percent loss of specimen trees on unimproved mountain property, or 0.6 percentage points more than on improved mountain property. Specimen trees were more valuable on unimproved than on improved tracts, in the opinion of real estate

Table 14. Change in the Market Value of Trees on Mountain Property with Five Percent Specimen Trees 24 Inches dbh or More, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| With and Without Specimen Trees | Value of 106 Trees Per Acre Six Inches dbh or More | |
|---|---|---|
| | Improved | Unimproved |
| Without Specimen Trees | $ 9,571 (5,893)[c] | $8,071 (4,920) |
| With Five Percent Specimen Trees | $10,500 (5,142) | $9,162 (5,525) |
| Change in Value[a] | $ 929 | $1,091 |
| Percent Change, Increase | 9.71 | 13.52 |
| Decrease | -8.85 | -11.91 |
| Elasticity[b], Increase | 1.94 | 2.70 |
| Decrease | -1.77 | - 2.38 |

a. Fourteen appraisers reported no change in property values with 5 percent specimen trees; median and mode were zero.

b. Average elasticity calculated as percent change in value of trees divided by 5 percent change in the number of trees.

c. Values in parentheses are standard deviations.

Table 15. Market Value of Four Specimen Trees 24 Inches dbh or More on Mountain Property With and Without 50 Percent Kill, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Specimen Trees With and Without Insect Infestation | Value of Trees per Acre | |
|---|---|---|
| | Improved | Unimproved |
| Value of Four Specimen Trees | $6,214 (5,551)[b] | $5,738 (5,190) |
| With Loss of Two Specimen Trees to Insect Infestation | $1,762 (2,189) | $2,048 (1,565) |
| Change in Value[a] | -$4,452 | -$3,690 |
| Percent Change | -71.64 | -64.31 |

a. All appraisers reported property values would increase with the presence of four specimen trees, and decrease with the loss of two of them.

b. Values in parentheses are standard deviations.

appraisers. Five specimen trees per acre contributed an average of $186 to $218 each to the value of improved and unimproved mountain property on the Front Range of the Rocky Mountains.

Real estate appraisers reported that a few specimen trees contributed more value to mountain property when they were the only trees present than when they were interspersed with mixed age stands of 106 trees six inches dbh or more per acre. The market value of four specimen trees was reported as $6,214 on improved and $5,738 on unimproved tracts with no other trees present. This was equal to an average value of $1,554 per tree on improved and $1,435 per tree on unimproved mountain property. This was about six times the value reported for specimen trees in mixed age stands.

The loss of two of the four specimen trees to insect infestation would reduce the value of mountain property by $2,226 per tree lost on improved and by $1,845 per tree lost on unimproved tracts. These results suggest that the value of specimen trees rises with increased scarcity of trees. When a few large trees are present in isolated stands, loss of one specimen tree reduces the value of mountain property more than the loss of five specimen trees interspersed in mixed stands of 106 trees per acre six inches dbh or more.

Change in Species

Table 16 shows the effect of change in the predominant species of trees on mountain property from ponderosa pine to douglas fir. Ponderosa pine have been killed by mountain pine beetle infestation in Front Range forests of the Rocky Mountains, while douglas fir are subject to stinting by spruce budworm infestation, causing discoloration and defoliation of newly grown needles which seldom kills the trees. Informed buyers consider the douglas fir superior to ponderosa pine because of this disease resistance. However, douglas fir tend to occur at higher elevations and on moist north facing slopes.

Real estate appraisers on the Front Range reported that the market value of trees per acre would increase by 0.05 percent with each one percent increase in the proportion of douglas fir forest on improved mountain property. The average elasticity of tree values with respect to the proportion of douglas fir on mountain property was calculated as 0.05 in the range of 1-100 percent of 106 trees per acre, with all other variables unchanged.

The effect of species of trees was virtually identical on unimproved mountain property. Value of trees per acre would increase by 0.06 percent with one percent increase in the proportion of douglas fir on unimproved mountain property. This suggests that protection of property values related to forest quality would be of equal importance on both improved and unimproved mountain property, in the opinion of real estate appraisers.

Table 16. Change in the Market Value of Trees on Mountain Property with Change in Species from Ponderosa Pine to Douglas Fir, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| Change in Species | Value of 106 Trees per Acre Six Inches dbh or More | |
|---|---|---|
| | Improved | Unimproved |
| With Ponderosa Pine | $ 9,571 (5,893)[c] | $8,071 (4,920) |
| With Douglas Fir | $10,079 (6,667) | $8,579 (5,853) |
| Change in Value[a] | $ 508 | $ 508 |
| Percent Change | 5.31 | 6.29 |
| Elasticity[b] | 0.05 | 0.06 |

a. The change in value reported by 17 appraisers was zero for both improved and unimproved mountain property.

b. Average elasticity calculated as percent change in value of trees divided by 100 percent change in species.

c. Values in parentheses are standard deviations.

Distribution of Trees

Table 17 shows the effect of an insect infestation killing all of the trees on part of mountain property. The market for mountain property may reflect the fact that some prospective buyers would avoid those tracts with evidence that up to one-half of the forest has been clear-cut, even though the same number of trees per acre remain on the property in a concentrated area. However, for some prospective buyers this would not be the case, as clear-cut of up to one-half of the forest would open up a vista and ease construction, while the same number of trees per acre remain on the property in a concentrated area.

Real estate appraisers on the Front Range reported that the market value of trees per acre would decrease by -0.29 percent with each one percent increase in non-forested clearing resulting from insect infestation of improved mountain property. The average elasticity of tree values with respect to distribution of trees was calculated as -0.29 percent in the range of 1-50 percent concentration of trees on one-half of one-acre tracts, all other variables unchanged.

The effect of distribution of trees was virtually identical on unimproved mountain property. Value of trees per acre would decrease by -0.29 percent with each one percent increase in non-forested clearing on unimproved mountain property. This suggests that the effect of an insect infestation killing all of the trees on part of mountain property would have an equal effect on the market value of improved and unimproved tracts, in the opinion of real estate appraisers.

Table 17. Change in the Market Value of Trees on Mountain Property with Change in the Distribution of Trees, in the Opinion of 21 Real Estate Appraisers, Front Range, Colorado, 1980.

| With and Without Change in Distribution | Value of 106 Trees per Acre Six Inches dbh or More | |
|---|---|---|
| | Improved | Unimproved |
| Without Concentration of Trees | $9,571 (5,893)[c] | $8,071 (4,920) |
| With Trees Concentrated on 50 Percent of Site | $8,350 (5,060) | $6,895 (3,861) |
| Change in Value[a] | -$1,221 | -$1,176 |
| Percent Change | -14.62 | -14.57 |
| Elasticity[b] | - 0.29 | - 0.29 |

a. The change in value reported by 10 appraisers was zero for both improved and unimproved mountain property.

b. Average elasticity calculated as percent change in value of trees divided by 50 percent random distribution of trees on a one acre tract.

c. Values in parentheses are standard deviations.

## REGROWTH OF INSECT DAMAGED FOREST

Table 18 shows the effect of the regrowth of an insect damaged forest on the contribution of trees to the market value of improved and unimproved mountain property. Results of the appraiser survey were utilized to estimate the effects of change in the size of ponderosa pine trees as future regrowth occurs on mountain property after mountain pine beetle infestation. Such information could improve the accuracy of converting the reported present value to annual value of trees on Front Range mountain property with and without mountain pine beetle control.

It should be noted that Table 18 assumes no recovery of the damages to forest values during the first 20 years after mountain pine beetle kills trees on mountain property. This is based on the belief that there would be little or no recovery of property values from the loss of trees until replacement trees reach five feet in height, equivalent to approximately one inch dbh. This would depend on growth conditions at the affected forest sites. If seedlings and small trees were present in the undercover at the time of attack, pine beetle kill of large trees may regrow to one inch dbh in 5-10 years. The same may be true in the case of replanting forests after a beetle attack. However, on many north facing dry slopes of the Front Range, natural reseeding of ponderosa pine may occur very slowly if at all. Meyer [1966] estimated that ponderosa pine tree regrowth would reach 1.2 to 1.7 inches dbh in 20 years, with conditions similar to the Front Range of Colorado, i.e., site index of 40-50.

The results of this study indicate that approximately 20 years after an initial mountain pine beetle attack, lost trees usually will be replaced by new growth averaging 1.7 inches dbh. With such small trees, the contribution of

Table 18. Effect of Regrowth of an Insect Damaged Forest on the Value of Trees, Improved and Unimproved One Acre Tracts, Front Range, Colorado, 1980 to 2080.

| Year | Tree Diameter, Inches dbh[a] | Improved | | Unimproved | |
|---|---|---|---|---|---|
| | | Value of Trees | Index of Recovery | Value of Trees | Index of Recovery |
| 0 | 0 | $ 0 | 0 | $ 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 |
| 20 | 1.70 | 4,464 | .58 | 3,887 | .60 |
| 25 | 2.63 | 5,219 | .67 | 4,523 | .69 |
| 30 | 3.55 | 5,861 | .76 | 5,046 | .77 |
| 35 | 4.47 | 6,431 | .83 | 5,498 | .84 |
| 40 | 5.40 | 6,949 | .90 | 5,903 | .90 |
| 45 | 6.32 | 7,430 | .96 | 6,272 | .96 |
| 50 | 7.25 | 7,843 | 1.01 | 6,585 | 1.00 |
| 55 | 7.85 | 8,160 | 1.05 | 6,822 | 1.05 |
| 60 | 8.53 | 8,464 | 1.09 | 7,049 | 1.08 |
| 65 | 9.21 | 8,758 | 1.13 | 7,266 | 1.11 |
| 70 | 9.84 | 9,042 | 1.16 | 7,474 | 1.15 |
| 75 | 10.57 | 9,317 | 1.20 | 7,675 | 1.18 |
| 80 | 11.25 | 9,584 | 1.23 | 7,869 | 1.21 |
| 85 | 11.94 | 9,844 | 1.27 | 8,056 | 1.23 |
| 90 | 12.62 | 10,098 | 1.30 | 8,238 | 1.26 |
| 95 | 13.30 | 10,345 | 1.33 | 8,415 | 1.29 |
| 100 | 13.98 | 10,587 | 1.36 | 8,587 | 1.32 |

a. Growth of managed ponderosa pine stands with a 10-year cutting cycle and site index of 50[Myers, 1966; 14].

trees to improved mountain property values would equal $4,464 per acre, compared to $3,887 per acre of unimproved mountain property. This represents a 58 percent recovery of the initial value of trees on improved mountain property before the mountain pine beetle infestation occurred, and a 60 percent recovery of the initial value of trees on unimproved mountain property.

With subsequent increases in the size of replacement trees, the contribution of trees to the value of improved mountain property would increase. For example, 35 years after an initial mountain pine beetle attack, the contribution of trees to the value of improved mountain property would increase to $6,431 per acre, compared $5,498 per acre of unimproved mountain property. This represents a 83 percent recovery of the initial value of trees on improved mountain property before the mountain pine beetle infestation occurred, and 84 percent recovery of the initial value of trees on unimproved mountain property.

Full recovery of the contribution of trees to mountain property values would occur approximately 50 years after an initial mountain pine beetle attack when it is estimated that regrowth of an insect damaged ponderosa pine forest would reach 7-8 inches dbh. This may be somewhat low as the average size of mountain pine beetle killed trees in Colorado has been reported as approximately 10 inches dbh [McCambridge, Hawksworth, and Laut, 1981]. With full recovery of forest quality, the contribution of trees to improved mountain property values would equal $7,843 per acre, compared to $6,585 per acre of unimproved mountain property.

For purposes of benefit cost analysis, it can be assumed that no damages to Front Range mountain property would be incurred beyond a growth cycle of 50 years. It is interesting to note, however, that the contribution of trees to mountain property values would continue to increase with tree growth beyond 50 years at

least to 100 years with average tree size of 14 inches dbh. The results presented in an earlier section of this report suggest that tree values would continue to increase with forest growth to 24 inches dbh. The beneficial effect of forest growth on mountain property values from 8-24 inches dbh would be lost for 50 years, after an initial mountain pine beetle attack. It would be strictly correct to include these damages in the benefit cost calculation. They would be estimated on the basis of the following equations:

| | | |
|---|---|---|
| Contribution of trees to improved property values, | <50 years | $= 20.9785(-1.99 + .0847YEAR)^{.5494} + 16.52$ |
| | ≥50 years | $= 20.9785(.3598 + .1362YEAR)^{.5494} + 16.52$ |
| Contribution of trees to unimproved property values, | <50 years | $= 22.6894(-1.99 + .1847YEAR)^{.4581} + 9.91$ |
| | ≥50 years | $= 22.6894(.3594 + .1362YEAR)^{.4581} + 9.91$ |

Where the contribution of trees to property values (in $100s) is the dependent variable, and YEAR equals the year in the regrowth cycle forced through the mean of tree values.

Mountain property is owned because it provides a stream of productive services. The present value of forest quality is defined in terms of changes in the annual value of these services. However, in this study it was the present value of the contribution of trees to the market value of mountain property which was reported by appraisers, and inferences about the stream of annual values requires converted the reported present value to annual values. Including the effect of regrowth of an insect damaged forest has a substantial effect on accuracy of the conversion of the reported present value to annual values. For example, the present value of $1 loss of improved mountain property values annually over a 50 years growth cycle of ponderosa pine would be $18.45 without including regrowth of an insect damaged forest in the calculation, and $12.88 with regrowth of the

damaged forest included in the calculation. By comparison, the present value of $1 loss of unimproved mountain property values annually over 50 years growth cycle of ponderosa pine would total $22.49 without including regrowth, compared to $14.53 with regrowth effects included. Thus, including regrowth effects in the calculation reduces the present value estimate by 30.2 to 35.4 percent per $1 of annual value. Both of these comparisons assume that development of residences in mountain subdivision would continue to grow at an annual rate of 4.8 percent and the plotting of unimproved lots at an annual rate of 6.0 percent, the compound annual growth rates estimated for 1970-1980 on the Front Range of Colorado. Present value was calculated for a 50 year planning period with a 10 percent discount rate.

A 10 percent discount rate is based on an opportunity cost of capital averaging 12 percent, a marginal income tax rate of 30 percent, and property tax rate of 2 percent on owner occupied mountain homes [Freeman, 1980]. Moreover, a 10 percent discount rate conforms with the U.S. Office of Management and Budget guideline requiring present value of benefit and cost of government programs be calculated using 10.0 percent and at a lower agency approved rate of discount. The U.S. Forest Service currently uses a 4.0 percent discount rate. To convert the 10.0 percent rate to 4.0 percent, multiply by approximately 2.17.

## APPLICATION TO CONTROL DECISIONS

Table 19 shows the economic efficient level of annual expenditure on mountain pine beetle and spruce budworm control by owners of improved and unimproved mountain property, based on the market value of trees in the opinion of real estate appraisers. If owners incur no costs of forest management such as insect control, the optimum number of trees on mountain property would be where total present value to owners is maximized and marginal value is zero. Based on the appraised market value of trees on private property in Front Range forests, this would exceed 128 trees per acre six inches dbh or more. With the introduction of costs of forest management such as to prevent insect infestation, the optimum number of trees to protect would fall. The optimum number of trees per acre, on grounds of economic efficiency, would occur where marginal benefit equals marginal cost per tree.

Table 19 shows that with marginal cost of forest management including insect control equaling about $0.90 per tree annually, the optimum number of trees to protect on improved mountain property would be 100 trees per acre. This would be equivalent to an insect control program which sprayed every three years at marginal cost of $2.70 per tree or a thinning program to encourage vigorous growth every ten years at a marginal cost of approximately $9 per tree.

With the protection of 100 trees per acre, average annual benefit would equal $7.57 per tree. In the case of the purchase of commercial insect control services, marginal cost would equal the average price paid. Thus, the annual benefit cost ratio of an owner's insect control program would be calculated as $6.15/$0.90 = 8.4. This means that for a $1 expenditure on forest insect control, owners would receive benefit of $8.40.

Table 19. Sensitivity of the Economic Efficient Level of Annual Owner Expenditure on Mountain Pine Beetle Control to Number of Trees per Acre on Improved and Unimproved Mountain Property, Front Range, Colorado, 1980.

| Number of Trees per Acre | Efficient Level of Annual Expenditure per Tree[a] (Marginal Benefit = Marginal Cost) | | Average Annual Benefit per Tree | | Benefit Cost Ratio of Control Program | |
|---|---|---|---|---|---|---|
| | Improved | Unimproved | Improved | Unimproved | Improved | Unimproved |
| 10 | $3.78 | $2.87 | $54.60 | $47.43 | 14.4 | 16.6 |
| 25 | 3.30 | 2.54 | 23.47 | 20.60 | 7.8 | 8.1 |
| 50 | 2.50 | 1.99 | 13.43 | 11.43 | 5.4 | 5.7 |
| 75 | 1.70 | 1.44 | 9.66 | 8.19 | 5.7 | 5.7 |
| 100 | 0.90 | 0.89 | 7.57 | 6.44 | 8.4 | 7.2 |
| 125 | 0.10 | 0.34 | 6.15 | 5.27 | --- | --- |

a. Reported present values were converted to annual values based on a perpetual benefit of trees with sustained yield forest practices, where annual value equals present value times the rate of discount. A 10 percent discount rate was based on an opportunity cost of capital averaging 12 percent, a marginal income tax rate of 30 percent, and property tax rate of 2 percent on owner occupied mountain homes [Freeman, 1980].

It should be noted that these recommended levels of mountain pine beetle control are based on a restricted case, average private market value of trees contingent on changes in the number of live trees six inches dbh or more on the property. Omitted from these calculations are other owner values such as resulting from discoloration of needles during the second year after an initial mountain pine beetle attack and for the duration of a spruce budworm outbreak, dead and down trees during approximately the 2-10 years after initial insect attack, loss of specimen trees, and other private values. Also omitted are the external values associated with trees on adjoining property viewed from an individual homeowner's property, and the effect of projection of tree values with continued development of mountain subdivisions over the next 50 years, and recovery of tree values with regrowth of beetle damaged forest. The economic efficient level of expenditure on forest insect control by an association of homeowners and/or a public agency would be more than an individual owner who makes the decision solely on the basis of the market value of trees on his mountain property.

Table 20 summarizes the effect of insect infestation on the aggregate present value of trees in the Front Range of the Colorado Rocky Mountains. The average market values reported by the sample of real estate appraisers was expanded to the population of 62,000 improved properties and 112,000 unimproved properties in 1980. Implicit in this expansion is the conservative assumption that improved and unimproved mountain property averages one acre in size. Also, it should be noted that future development of mountain subdivisions would increase the effect of insect infestation shown here.

Table 20. Summary of the Effect of Insect Infestation on the Estimated Market Value of Trees on Improved and Unimproved Mountain Property, Front Range, Colorado, 1980.

| Forest Quality Effect | Duration of Effect | Effect of One Percent Insect Infestation | | Effect of 15 Percent Insect Infestation | | Aggregate Present Value of 15 Percent Insect Infestation in Front Range Forests ($1,000s) |
|---|---|---|---|---|---|---|
| | | Percent | Present Value per Acre | Percent | Present Value per Acre | |
| Number of Live Trees Six Inches dbh or More on Mountain Property | 10-19 yrs, constant 20-50 yrs, declining | | | | | |
| Improved | | 0.14 | $ 10.33 | 2.03 | $ 155 | $ 9,610 |
| Unimproved | | 0.15 | 9.93 | 2.30 | 149 | 16,670 |
| Number of Live Trees Six Inches dbh or More on Adjacent Property | 10-19 yrs, constant 20-50 yrs, declining | | | | | |
| Improved | | 0.12 | 11.93 | 1.79 | 179 | 11,098 |
| Size of Trees | 10-19 yrs, constant 20-50 yrs, declining | | | | | |
| Improved | | 0.53 | 57.15 | 7.95 | 857 | 53,134 |
| Unimproved | | 0.54 | 50.16 | 8.10 | 752 | 84,135 |
| Expectation of 15 Percent Insect Damage | continuous during outbreak | | | | | |
| Improved | | 0.94 | 89.52 | 14.10 | 1,343 | 83,266 |
| Unimproved | | 0.92 | 73.80 | 13.80 | 1,107 | 123,853 |
| Visible Discoloration of Needles on Mountain Property | second year after initial mountain | | | | | |
| Improved | pine beetle; | 2.48 | 193.00 | 37.30 | 2,895 | 179,490 |
| Unimproved | continuous during | 2.06 | 134.27 | 30.87 | 2,014 | 225,330 |
| on Adjacent Property | spruce budworm | | | | | |
| Improved | defoliation | 1.07 | 83.47 | 16.10 | 1,252 | 77,624 |
| Unimproved | | 1.85 | 120.93 | 27.81 | 1,814 | 202,954 |
| In the Far View | | | | | | |
| Improved | | 0.16 | 12.80 | 2.47 | 192 | 17,904 |
| Unimproved | | 0.64 | 41.93 | 9.64 | 629 | 70,374 |
| Total Effect of Visible Discoloration | | | | | | |
| Improved | | 3.73 | 289.27 | 55.9 | 4,339 | 269,018 |
| Unimproved | | 4.55 | 297.27 | 68.32 | 4,459 | 498,882 |
| Distribution of Live Trees on 85 Percent of Property | 1-19 yrs, constant 20-50 yrs, declining | | | | | |
| Improved | | 0.29 | 24.42 | 4.35 | 366 | 22,692 |
| Unimproved | | 0.29 | 23.52 | 4.35 | 353 | 39,494 |
| Changes in Species, from Ponderosa Pine to Douglas Fir, 15 Percent | continuous 20-6 | | | | | |
| Improved | | 0.05 | 5.08 | 0.75 | 76 | 4,712 |
| Unimproved | | 0.06 | 5.08 | 0.90 | 76 | 8,520 |
| Specimen Trees, 5 Percent | 1-19 yrs, constant | | | | | |
| Improved | 20-180 yrs | 1.94 | 185.80 | | | |
| Unimproved | | 2.70 | 218.20 | | | |

The largest effect on tree values was visible forest insect damage when needles turn rust color from mountain pine beetle infestation of ponderosa pine and new growth is defoliated by spruce budworm infestation of douglas fir. With 15 percent of the trees on the property, in the near view, and the far view showing discolored on defoliated needles, present value of trees on improved property would decrease by $269.0 million, compared to $498.9 million on unimproved property. This would occur during the second year after the initial mountain pine beetle attack of ponderosa pine trees, and would not re-occur once the needles fall from dead trees by the third year. It is possible that visible insect damage effects would occur throughout the period of time in which spruce budworm defoliate douglas fir trees continuing for many years. However, appraisers were not specifically asked to report the effect of spruce budworm defoliation, just the effect of 15 percent visible insect damage.

The second largest effect on trees values was reported when forest entomologists predict a general outbreak of forest insect infestation which would kill 15 percent of the trees on mountain property within five years. With the expectation that 15 percent of the trees would be killed, present value of trees on improved property would decrease by $83.3 million, compared to $123.9 million on unimproved property. This would occur during the period of initial outbreak and continue until either damage occurred to trees on the property or the outbreak ended.

The long-run effects of forest insect infestation would be: changes in the number of trees on mountain property, on adjacent property in the near view, distribution of live trees on the property, average size of surviving trees, and loss of large specimen trees. With 15 percent fewer trees on improved mountain property the present value of trees would decrease by an estimated $9.6 million,

compared to $16.7 million on unimproved property. With 15 percent fewer trees on adjacent property in the near view, the present value of trees to owners of improved property would decrease by $11.1 million. If as is often the case, forest insects attack 15 percent of the trees in a concentrated area on part of the property, the present value of trees on improved mountain property would decrease by an estimated $22.7 million, compared to $39.5 million on unimproved property. This would be the effect on tree values from clear-cutting 15 percent of mountain property. With 15 percent reduction in the average size of surviving trees, the present value of trees to owners of improved property would decrease by $53.1 million, compared to $84.1 million on unimproved property. However, this effect would not be constant over the 50 year tree growth cycle. It would decline as replacement trees grow from 1-7 inches dbh in the approximate 20-50 year period after the initial forest insect infestation. In addition, there would be a substantial loss in the value of trees to mountain property owners when a few large specimen trees are killed by insect infestation. However, it was not possible to provide an estimate of the effect of the loss of large specimen trees for the Front Range because the number of such magnificent trees lost has not been estimated.

# CONCLUSIONS

The purpose of this study was to develop and apply a procedure for measuring the contribution of trees to the market value of improved and unimproved mountain property, in the opinion of real estate appraisers. The results of the study provide an empirical basis for estimating the market value to mountain property owners from mountain pine beetle and spruce budworm infestation control programs, both private and public. Real estate appraisers reported the maximum market value of trees contingent on changes in several important forest quality variables including: number of trees six inches dbh on mountain property, and in the new view on adjacent property; size of trees, presence of large specimen trees, expectation of insect damage, visible insect infestation, change in species, and distribution of trees on the property. Without such information, insufficient resources would be allocated by property owners and society to protection of forest quality.

In addition to the contribution of trees to the market value of mountain property reported here, the general public may value the preservation of forest quality and be willing to pay for: the option to have access to or purchase property with outstanding forest resources in the future; the knowledge that forest quality exists and is protected; and the satisfaction from the bequest of forest quality to future generations. Moreover, the market value of forest quality on mountain property reported here are constrained by the limited household income of buyers and other variables [Gordon and Knetsch, 1979]. There may be psychological values associated with forest quality which exceed the contribution of trees to property values reported here [Driver and Brown, 1975].

In addition to the contribution of trees to the market value of mountain property, there may be long-run ecological values which are not included here. It is difficult for biologists to predict what these might be let alone measure and incorporate them into a property value estimate. For this reason it seems that the present market value of trees on mountain property represents a conservative estimate of the total value to society of protecting forest quality. The inability of economic analysis to place a dollar value on unknown ecological effects should be recognized in making decisions about mountain pine beetle and spruce budworm infestation control programs.

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**Colorado State University**
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80523

Interviewer _____
Date _____ Time _____
Location _____
Project Number _____

## MOUNTAIN REAL ESTATE AND FOREST QUALITY

1. For how many years have you been a real estate appraiser? _____ years. For how many years have you appraised mountain real estate? _____ years. Designations _____

2. In your opinion, does the number of trees on a one acre lot affect the market value of mountain real estate? Yes ___ No ___ Comments _____

3. How important are trees to purchasers of mountain real estate? Answer 4 parts.

| | Extremely Important | Very Important | Moderately Important | Somewhat Important | Not Important |
|---|---|---|---|---|---|
| a. Trees on property purchased? | ____ | ____ | ____ | ____ | ____ |
| b. Trees on adjoining property (the near view)? | ____ | ____ | ____ | ____ | ____ |
| c. Trees in the far mountain view? | ____ | ____ | ____ | ____ | ____ |

d. Comments: _____

4. How important are trees to purchasers of mountain real estate relative to other characteristics of the site?

| | Much More | More | Same | Less | Much Less |
|---|---|---|---|---|---|
| a. Rock outcroppings | ____ | ____ | ____ | ____ | ____ |
| b. Nearness to streams and lakes | ____ | ____ | ____ | ____ | ____ |
| c. Topography | ____ | ____ | ____ | ____ | ____ |
| d. Rocky mountain view | ____ | ____ | ____ | ____ | ____ |
| e. Other (specify) _____ | ____ | ____ | ____ | ____ | ____ |
| f. Other (specify) _____ | ____ | ____ | ____ | ____ | ____ |

PLEASE KEEP IN MIND THAT THE NEXT SEVERAL QUESTIONS ARE A HYPOTHETICAL EXPERIMENT INTENDED TO PROVIDE SOME NOTION OF HOW THE NUMBER OF TREES AFFECTS THE MARKET VALUE OF IMPROVED AND UNIMPROVED MOUNTAIN REAL ESTATE

Assume that the properties shown in the pictures are exactly the same except for number of trees per acre.

Characteristics common to all sites:

| | | | |
|---|---|---|---|
| Size of lot: | Roughly one acre (40,000 sq. ft.) | Schools: | All schools equally close |
| Topography: | Gently sloping land, little or no rolls | Location: | All lots in the same subdivision in the vicinity of Estes Park, Colorado |
| Utilities: | Electricity, sewer and water | Tree Species: | Ponderosa Pine in a scattered arrangment |
| Access: | Public road in front | House: | 1,500 to 2,000 square feet of living space, 2 baths, 2 car garage, fireplace, 3 bedrooms, family room |

5. Estimate the contribution of trees to the market value of unimproved one acre lots with forest quality like picture ____ with ____ trees per acre, in relation to picture A which has a market value of $_____ and is assumed to be comparable except that it has no trees.* (Repeat question for low, medium, and high tree pictures and record values below.)

Pictures, Number of Trees Per Acre, and Estimated Market Value

| No trees | Low ____ trees | Medium ____ trees | High ____ trees | Very High ____ |
|---|---|---|---|---|
| $_____ | $_____ | $_____ | $_____ | $_____ |

6. Estimate the contribution of trees to the market value of improved one acre tracts with forest quality like picture with ____ trees per acre, in relation to picture A which has a market value of $_____ including a $____ lot (Q.5) and an $80,000 house. Assume that properties B-F are exactly the same except for number of trees.* (Repeat question for the low, medium and high tree pictures and record values below.)

Pictures ____, Number of Trees Per Acre and Estimated Market Value

| No trees assumed | Low ____ trees | Medium ____ trees | High ____ trees | Very High ____ trees |
|---|---|---|---|---|
| $_____ | $_____ | $_____ | $_____ | $_____ |

7. *(Ask if respondent reports that market value is not affected by forest quality:) What is the reason?

   a. Property owners are not adversely affected by forest quality?
   b. You believe mountain property is already overvalued?
   c. You believe it is unfair to expect property owners to pay for forest quality which should be provided by public agencies from tax revenues?
   d. Other? (specify) _____

8. What would be the neighborhood effect of varying levels of forest quality? Assume that the view from the front of the residential tracts would vary as in the pictures. Estimate the change in current market value of your highest valued improved tract.

   View from Front, Number of Trees Per Acre, and Estimated Market Value

| No trees | Low ____ trees | Medium ____ trees | High ____ trees | Very High ____ trees |
|---|---|---|---|---|
| $_____ | $_____ | $_____ | $_____ | $_____ |

9. a. Assume that 15% of the trees in the picture entitled high trees were afflicted with pine beetle damage. What would be the value of the unimproved lot? $_____ Improved lot $_____
   b. Assume 15% of the trees of the neighboring lots viewed from the lot entitled high trees were afflicted with pine beetle damage. What would be the value of the unimproved lot? $_____ Improved $_____
   c. Assume you can see a far distant view from high tree lot, and that the distant mountain slope of dense tree cover has 15% pine beetle damage (brown trees). What would be the value of the unimproved lot? $_____ Improved_____

10. How would your estimates of tree values change if conditions changed in the following ways? Answer in terms of change in the total value reported for your highest priced picture.

    a. Arrangement of trees on property would change from a scattered pattern to a concentrated grouping on one-half of the lot with one-half open space. Unimproved $_____ Improved $_____
    b. Predominant species of trees on property would change from Ponderosa Pine (which are subject to beetle kill) to Douglas Fir (which are attacked by spruce budworm, causing defoliation and browning but which seldom kills the trees). Unimproved $_____ Improved $_____
    c. Forest entomologists report that one-half ot the trees on the lot would be killed by insect infestation within five years. Unimproved $_____ Improved $_____
    d. Residential tracts would have the same number of trees but the 6 inch dbh minimum tree size (or diameter) would change to:
       1) One-half as large (3 inches dbh). Unimproved $_____ Improved $_____
       2) Twice as large (12 inches dbh). Unimproved $_____ Improved $_____
       3) Five percent of trees would be magnificent specimens, four times as large (24 inches dbh). Unimproved $_____ Improved $_____
    e. Size of lot would change from one acre to one-half acre (while tree density per acre and tree size would not change). Unimproved $_____ Improved $_____
    f. Size of lot would change from one acre to two acres (while tree density per acre and tree size would not change). Unimproved $_____ Improved $_____
    g. Basic value of house and neighboring houses would double from $80,000 to $160,000 (plus lot). $_____
    h. Basic value of house and neighboring houses would fall from $80,000 to $40,000 (plus lot). $_____

11. a. What is the value of a lot with four specimen trees (like specimen tree picture) as compared to lot with no trees of $_____? Unimproved $_____ Improved $_____
    b. What would be value if 2 of the 4 specimen trees were afflicted with pine beetle damage? Unimproved $_____ Improved $_____

12. Do you have any comments about forest quality management which would help make Colorado a better place to own mountain real estate? _____